MIX DESIGN AND AGGREGATE REQUIREMENTS FOR STONE MATRIX ASPHALT MIXTURES

By

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DEDICATION

To my mother and father, who nurtured me, inspired me, supported me, and gave me the confidence to venture toward my own goals.

and

To my girls: Ronda, Anna Grayce and Clara, who have lovingly and patiently helped me reach this goal with my identity intact.

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Abstract of Dissertation Presented to the Graduate School
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Stone Matrix Asphalt (SMA) mixtures were developed in Europe where they have proven to be very resistant to rutting, cracking, and polishing. SMA mixtures are characterized by a stone-on-stone aggregate structure filled with a rich binder-filler mastic. Implementation of SMA in the United States began in 1991. The traditional method of design for SMA mixtures has utilized the Marshall procedure, but recipe formulations of component percentages and restrictive material guidelines persist. A better design method was needed that could provide an engineering basis for the selection and optimization of materials.

In this research study, SMA mixtures from several field projects and experimental mixtures containing typical Florida materials were tested in accordance with several well-known techniques used to evaluate conventional asphalt mixtures. These tests included

compaction and shear strength testing with the Gyratory Testing Machine; a rutting test using the Georgia Loaded Wheel Tester; a rutting test using a confined repeated-load procedure; resilient modulus tests at low, moderate, and high temperatures; the indirect tensile strength and strain test; wet/dry moisture damage tests, and a low-temperature diametral-creep compliance test.

Each of the rutting tests do indicate that the SMA mixtures are generally very resistant to permanent deformation. However, the procedure used to evaluate fatigue cracking indicated that many SMA mixtures were less resistant to fatigue than standard dense-graded mixtures. The validity of this assessment is uncertain. Tests on the mixtures and the aggregates show that some of the softer Florida limestones tend to be more prone to degradation which may lead to moisture damage and increase the potential for ravelling or loss of skid resistance. A preliminary assessment of the impact that SMA may have on the paving and aggregate supply industries indicates that due to limited application of this technology to heavy-traffic-type roadways the effect will be very minor.

CHAPTER 1
INTRODUCTION

1.1 Significance of Pavement Materials Research

The quest to extend pavement life has great economic importance. In the United States, an estimated $10.5 billion of hot mix asphalt is produced each year for highway construction and resurfacing pavements. In Florida, approximately $150 million is spent each year on hot mix asphalt placed on the state's highway system. Most of that is used for resurfacing of existing pavements that have reached their useful life .

Highway engineers must continually search for ways to improve the performance of pavements. The amount of traffic and the loads carried by our highway pavements has steadily increased through the years. It has become apparent over the past decade that many of the materials and procedures that have been conventionally used to design pavements are not suitable for the increase in traffic and heavy loads imposed upon them.

One technology that may have potential for improving the performance of heavily loaded pavements is the European concept of stone matrix asphalt (SMA). The European SMA mixtures have been heralded to have better highway performance than conventional dense-graded asphalt concrete (DGAC) mixtures used in the United States.

SMA mixtures have been said to have three primary advantages: high deformation (rutting) resistance, high resistance to cracking and ravelling, and high wear resistance [1].

These attributes are a result of several factors which distinguish SMA mixtures from DGAC mixtures.

1.2 Description of SMA Mixtures

The most unique characteristic of SMA mixtures is the aggregate gradation. SMA mixtures are said to be gap-graded with a very high proportion of coarse aggregate and a high mineral filler content. The gap in the aggregate gradation of SMA mixtures occurs in the size range between 4.75mm and 75μm, where little material is retained. The effect of the gap-gradation is evident in the core sample shown in Figure 1. The contact between coarse aggregate particles has been described as a stone-on-stone skeleton which provides the strength (i.e. rutting resistance) of the SMA mixture.

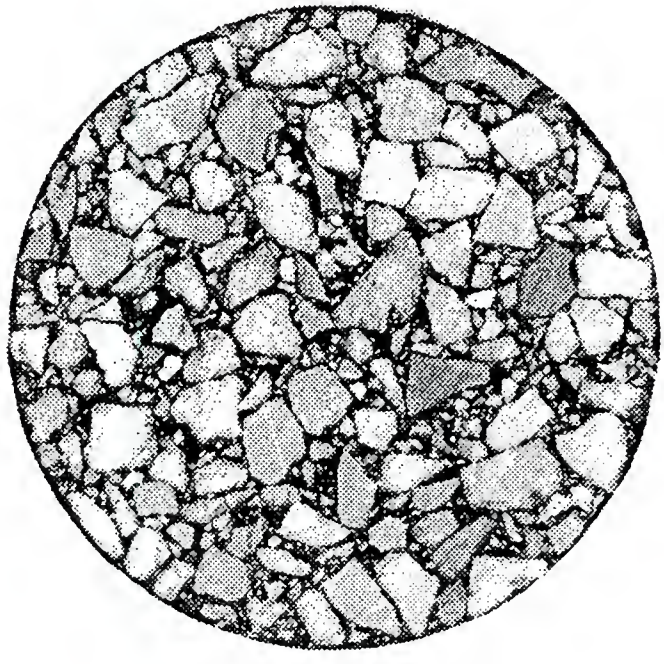

Figure 1. Cross Section of an SMA Core

The other unique feature of SMA mixtures is the binder mastic. In SMA mixtures, the asphalt binder combines with the mineral filler and added stabilizers to form a stiffened binder mastic to bond the aggregate particles together and provide durability to the mixture. Several types of stabilizing additives have been used in SMA mixtures including cellulose fibers, mineral fibers, and polymers. Without a stabilizing additive the binder will tend to drain to the bottom of the mixture during storage or transport between the hot-mix production facility and the paving operation at the roadway. The filler and stabilizing additives stiffen the binder at high temperatures without sacrificing flexibility of the binder to resist cracking.

1.3 Issues to be Resolved

There are, however, several issues regarding SMA mixtures that must be resolved before the technology can be effectively applied in Florida and many other states. The most important issue is cost effectiveness. European experience has been that SMA mixtures cost ten to twenty percent more than the conventional DGAC mixtures [2,3]. The increased costs are attributed to several factors such as the use of premium quality aggregates, the cost of additives, and slower production rates. Compared with the current DGAC mixtures, can SMA mixtures provide longer pavement service lives to offset the higher initial costs?

In Florida, the economics of SMA mixtures will depend primarily upon the suitability of the state's native aggregates. The soft limestones, which dominate Florida's aggregate market, have served well in the conventional DGAC mixtures. However, the

European recommendations adopted by the Federal Highway Administration (FHWA) [4] have been to limit SMA aggregates to very high quality materials. The SMA aggregate specifications suggested by FHWA are so restrictive that no native Florida aggregates meet the requirements. If it is determined that Florida's aggregates are not suitable for use in SMA mixtures, it is expected that importing acceptable aggregates from out of state would make SMA mixtures cost prohibitive in most of the state.

Another critical area of concern is the current practice of SMA mixture design. Selection of materials and component proportions for SMA mixtures has been traditionally based upon recipes and rules-of-thumb developed from experience in Europe. The optimum asphalt content for most SMA mixtures has been determined using only the volumetric elements of the Marshall mix design method. Considering the widely recognized deficiencies of the Marshall procedure, it is not surprising that many SMA designs are adjusted in the field after the start-up of production.

Possibly the most significant problem with the current practice of SMA mixture design is the total absence of performance-related, mixture strength or deformation tests which may indicate how well the mixture resists loading and environmental conditions in the field. Without such tests, it is impossible to compare the relative benefits of using alternative materials or to evaluate expected performance of SMA mixtures versus dense-graded mixtures. The primary reason for the lack of such testing is because SMA mixtures have generally performed poorly in many laboratory tests used to evaluate performance characteristics of DGAC mixtures. Based on the excellent performance history of SMA mixtures in Europe and in U.S. demonstration projects, it can be concluded that the tests

are inadequate rather than the SMA mixtures. Good mixture design tests should be able to predict, or at least indicate, the mixture's performance.

1.4 Objectives and Approach to Research

It is important to research the viability of the SMA mixtures containing currently utilized materials. Likewise it is also important to evaluate these SMA mixtures relative to the standard dense-graded mixtures. If it can be demonstrated that the current Florida aggregates are suitable in SMA mixtures, *and* that SMA mixtures will perform better than typical DGAC mixtures, the savings earned from longer lasting pavements may amount to several million dollars each year.

One approach to this research could be to simply construct test pavements with SMA mixtures and evaluate field performance. However, this approach is very costly, limited to the evaluation of only a few of the variables, and would probably take ten to twenty years to fully evaluate all aspects of performance. A more sensible approach is to conduct the research in the laboratory using tests which are representative of field conditions and clearly related to field performance. Therefore, the objectives of this project were developed to address two issues regarding SMA mixtures: mixture design and aggregate requirements.

To evaluate improved mix design for SMA mixtures, a combination of mixture tests were selected to assess the resistance of SMA mixtures to the four major types of flexible pavement distress: rutting, thermal cracking, fatigue cracking, and stripping. The tests used to characterize rutting resistance were Gyratory shear strength using the Corps

of Engineers Gyratory Testing Machine, rutting tests with the Georgia Loaded Wheel Tester, and deformation resistance measured in triaxial repeated-load tests. Fatigue and stripping resistance of SMA mixtures were evaluated using the indirect tensile strengths and resilient moduli of conditioned and unconditioned samples. Thermal cracking potential was evaluated using indirect tensile creep and resilient moduli tests.

Current aggregate requirements for SMA mixtures were thoroughly reviewed. Arguments of why certain aggregate requirements may or may not be necessary to ensure good mixture performance are presented. SMA aggregates from several field projects were evaluated in terms of traditional aggregate tests and a couple of new tests felt to be more indicative of performance. In particular, a new test was developed to assess aggregate degradation potential by comparing sample gradations before and after compaction tests of dry aggregates and SMA mixtures in the Corps of Engineers Gyratory Testing Machine.

A cost-effectiveness comparison of SMA mixtures and conventional asphalt mixtures can not be accurately assessed until typical production costs and life cycles are documented. A brief discussion is presented to focus on the implementation of SMA mixtures and its potential impact on the paving and materials industries in Florida.

In summary, the specific research objectives of this research are as follows:

1. Identify mixture tests which can be used to indicate the performance of SMA mixtures.

2. Recommend an appropriate testing protocol for the design of SMA mixtures that will enable the designer to choose the materials and proportions that will provide the greatest resistance to the major forms of pavement distress.
3. Establish more rational limits for aggregate quality parameters which are necessary to assure success in SMA mixtures.
4. Identify the aspects of the paving industry that will be most affected by the use of SMA mixtures in Florida.

The scope of the research was established so that test results could be related to performance. This was accomplished by obtaining eleven mixtures (or materials) from SMA projects constructed in six states between 1991 and 1993. The laboratory test results of these field proven materials and mixtures were used to establish a baseline of results for use in the evaluation of Florida materials and experimental mixtures. Six aggregate sources, typically used in asphalt mixtures and representative of the geologic and geographic range of aggregates used in Florida, were selected for the research.

1.5 Organization

This dissertation has been organized to present the literature review, research plan, testing, analysis, and findings in as clear and logical sequence as possible. Following this introductory chapter is a chapter on the historical development of SMA mixtures and their technological differences with typical dense-graded mixtures. A review of SMA mix design procedures and other tests used in SMA research is the topic of Chapter 3. The testing program for this study is presented in Chapter 4. Chapter 5 includes descriptions

of the materials and the mixture test procedures. The results of the SMA mixture tests are presented and analyzed in Chapter 6. A review of aggregate characteristics and aggregate tests is presented in Chapter 7. Chapter 8 consists of evaluations of the aggregate properties and characteristics for the materials used in this study. Chapter 9 presents an assessment of the mixture and aggregate tests covered in this study. Chapter 10 projects the impact of SMA mixtures on Florida highway construction, the probable role and extent of usage, and the changes that will be necessary in the hot-mix asphalt (HMA) industry and in the aggregate industry. Conclusions and recommendations are presented in Chapter 11.

CHAPTER 2
HISTORIC OVERVIEW OF SMA TECHNOLOGY

2.1 Origin of Stone Matrix Asphalt

SMA mixtures were developed over the past three decades in several of the northern European countries. Germany, where the SMA technology originated, has the most experience, with over 14,000 lane miles of SMA pavement. In 1989 and 1990, Germany placed nearly a million tons of SMA [5]. Sweden, Denmark, Norway, the Netherlands, Finland, Austria, France, and Switzerland all utilize the SMA concept to some degree. Each country has different requirements and different terminology. Splittmastixasphalt, grit mastic asphalt, stabinor, and HABS (hot asphalt with stone) are all names synonymous with stone matrix asphalt as it has been titled in the United States.

The SMA concept was initially developed in the 1960s as a pavement surface course to provide improved abrasion resistance under studded tires [2]. When studded tires were banned from most European countries in the early 1970s, the use of the SMA concept declined. However, from the performance of the early SMA pavements, it was recognized that the SMA mixtures were also very resistant to rutting and shoving under heavy traffic. Since most countries now prohibit studded tires, SMA mixtures have become used primarily to provide a highly stable pavement surface. In 1984, standard specifications for SMA mixtures were put into practice in Germany. Many other northern

European countries adopted slightly variant specifications for SMA mixtures in the late 1980s.

In addition to the wear resistance and rutting resistance of SMA mixtures, several other attributes have also been cited: improved durability [2,3,4], improved cracking resistance [2,6], very good skid resistance [2], reduced water spray [7], and reduced noise [8].

2.2 Comparison of SMA and DGAC Mixtures

Like conventional asphalt concrete, SMA mixtures are hot-laid, densely compacted mixtures composed of about 94 to 95 percent aggregate and about 6 to 7 percent asphalt by weight of total mix. However, the primary difference between conventional DGAC mixtures and SMA mixtures is the aggregate gradation. As shown in Figures 2 and 3, a typical aggregate gradation for DGAC consists of a uniform distribution of particle sizes, whereas SMA mixtures utilize a gradation which is dominated by a single particle size, typically between 9.5 mm and 4.75 mm, and contains few aggregate particles between 4.75 mm and 75 μm.

Figure 4 illustrates the effect of gradation for an SMA mixture and a typical DGAC mixture containing the same maximum aggregate size. The obvious and important detail evident from this figure is that the SMA gradation creates more contact between coarse aggregate particles. In the DGAC gradation, the large aggregate particles float in a structure dominated by fine aggregate particles. The stone-to-stone contact of SMA mixtures is said to provide a structural skeleton which is very resistant to deformation.

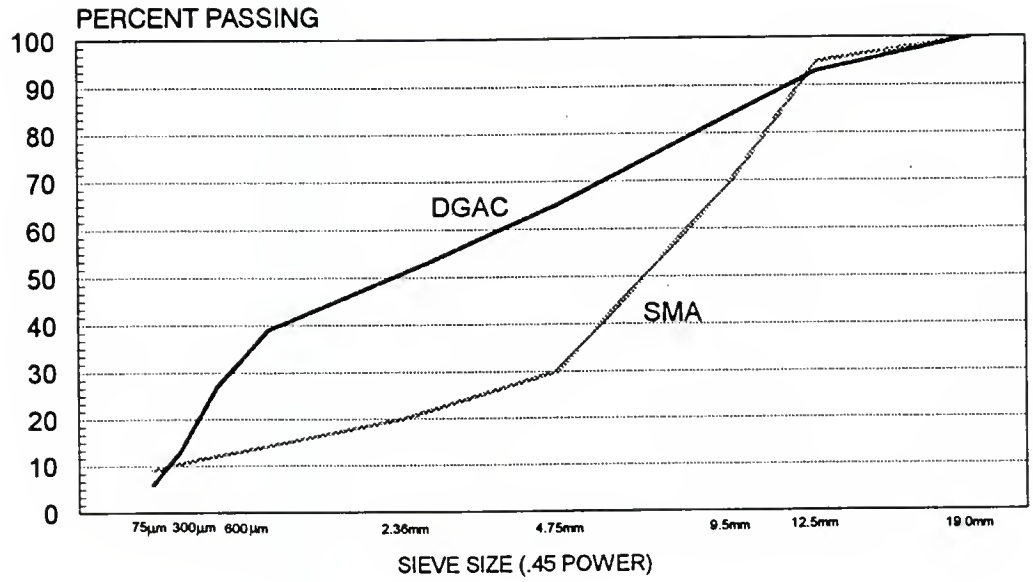

Figure 2. Plot of Typical DGAC and SMA Gradations

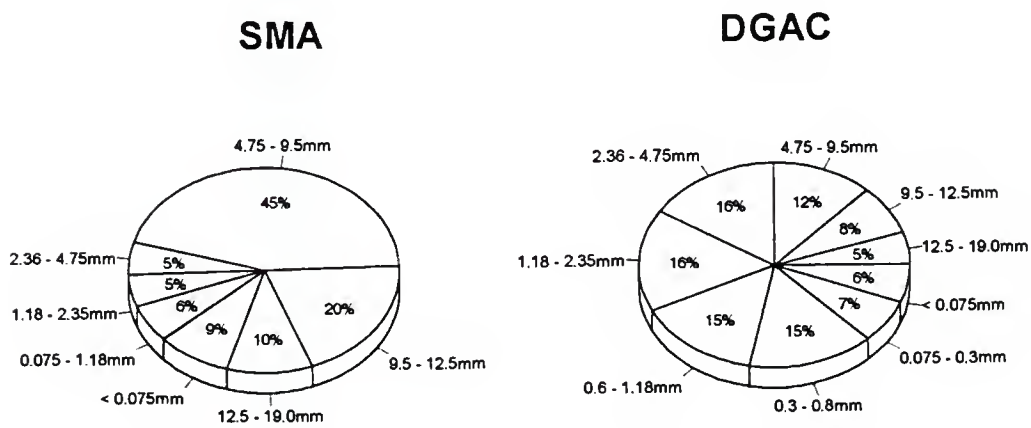

Figure 3. Typical Percentages of Aggregate Particle Sizes in SMA and DGAC Mixtures

Figure 4. Comparison of DGAC (top) and SMA (bottom) Aggregate Structures

The high percentage of essentially one-size coarse aggregate creates excellent particle interlock.

The durability of SMA mixtures is derived from the rich voidless mastic of asphalt, filler, and stabilizer. SMA mixtures in Europe generally have higher binder contents than dense-graded mixtures. The coarse aggregate gradation and the higher binder content together yield a thicker binder coating on the aggregate particles which holds the particles tightly together and provides greater resistance to binder aging.

2.3 Selection of Materials

In Europe, selection of materials for SMA mixtures is based primarily on experience. This applies to the selection of aggregates, fillers, stabilizers, and grades of asphalts.

Most references state that premium-quality, crushed aggregates must be used. Bellin [2] states that Germany requires "double crushed, tough, premium aggregates of definite size, soundness, shape, etc." and that the aggregates must have a high Polished Stone Value (PSV) for good skid resistance. The term "double-crushed" is unclear, and quantitative criteria corresponding to the descriptive requirements of "toughness" or "soundness" were not cited. A requirement that aggregates contain less than 20 percent flat and elongated particles was given. Aggregates commonly used in German SMA mixtures are gabbro, diabase, basalt, and granite. Limestones, sandstones, and "soft" aggregates are not used. Sweden, which still allows studded tires and uses SMA mixtures to provide abrasion resistance, has specification limits for impact crush strength, flakiness

index, and abrasion resistance [9]. Quartzite is cited as a commonly used aggregate in Swedish SMA mixtures. Danish specifications also require 100 percent crushed rock with a minimum flakiness value and a minimum brittleness value [10]. In references from other countries, specific aggregate requirements were not given although "crushed rock" was often used to describe the coarse aggregate.

Requirements for the fine aggregates are also unclear. Several references stated that fine aggregate shall be manufactured sand [11,12], whereas others appeared to allow manufactured sands, natural sands, or a combination of the two [10,13,14,15]. No test requirements for fine aggregates were given in the literature.

The most common type of filler used in European SMA mixtures appears to be limestone dust [2,12]. No specific requirements are provided in the literature. Tappenier [11] suggests that the filler should be as fine as possible so that it embeds in the asphalt film. According to Bellin [2], baghouse fines are not used much as filler in SMA mixtures.

A variety of stabilizers have been used in European SMA mixtures. Asbestos fibers were used in early SMA mixtures before studies indicated potential hazards with this material. Cellulose and mineral fibers appear to now dominate the stabilizer market. Cellulose fibers are used exclusively in Denmark and the Netherlands [10,13]. Sweden reportedly utilizes cellulose and mineral fibers on a equal basis [16]. Germany primarily uses cellulose fibers, but also permits mineral fibers, as well as siliceous acid and polymers [2,14]. In some cases, polymers and fibers are apparently used together in the same mixture. Granulated rubber and secret additives are also mentioned as stabilizers [3,6].

European asphalt cements are graded by the penetration test. Most countries utilize a 60 to 70 penetration asphalt for SMA mixtures [6,9,10,12]. In some cases a lower penetration asphalt is used for heavy trafficked pavements [13,14], or higher penetration asphalts are used for low volume roads or cold climates [9,10,12,13].

2.4 Design of SMA Mixtures

The European approach to design of SMA mixtures has been largely based upon rules-of-thumb and recipes for selecting and proportioning components. The literature indicates that proportioning of aggregates has been controlled to a large degree by narrow gradation bands developed from years of experience in each country. Most of the countries have several SMA gradations which are identified by the maximum particle size. Germany, for example, has gradation specifications for SMA mixtures with 5 mm, 8 mm, and 11 mm top size. Sweden utilizes larger top sizes of 12 mm and 16 mm. The 30-20-10 rule (30% passing the 4.75 mm sieve, 20% passing the 2.36 mm sieve, and 10% passing the 75 μm sieve) also appears to be used to determine aggregate proportioning in Sweden.

The practice of selecting the design binder content varies among the European countries, although all appear to require at least 6.0 percent binder in SMA mixtures. In some countries, such as the Netherlands [15], a specific binder content for each gradation is also specified as part of the recipe. In Sweden [17] and Denmark [10], minimum binder contents for each gradation are given and the Marshall procedure is used to determine the binder content which yields between 2 and 4 percent air voids. In Germany [18], the

practice is apparently to fix the binder content and to vary the gradation to achieve 2 to 4 percent voids using the Marshall procedure. Although none of the available European references stated how many blows are used in the Marshall compaction, it is assumed by nearly all U.S. references that 50 blows-per-face is used. Other than air voids, the European specifications did not identify other volumetric requirements, except for Denmark which requires a minimum VMA of 16 and voids filled between 78 and 93 percent. Stability and flow requirements are apparently not utilized by any of the countries. Several references [2,19], in fact, cautioned that misleading conclusions could be made by comparing low stability and high flow values obtained for SMA mixtures to properties of dense-graded mixtures.

2.5 The European Asphalt Study Tour

In September 1990, a group of U.S. pavement specialists toured six European countries to observe and learn about the asphalt pavement technologies, practices, and experiences that could be brought back to the U.S. The group consisted of 21 participants from FHWA, the paving industry, state highway agencies, and research organizations. The group was very impressed with the European pavements and shamelessly admitted that U.S. pavements were inferior [3]. One of the reasons that many of the European pavements performed so well was attributed to the durable SMA surface mixtures. Since the return of the study tour, the heralded SMA technology has been aggressively promoted in the United States.

2.6 Early SMA Projects in the United States

During 1991, four states (Wisconsin, Georgia, Michigan, and Missouri) constructed SMA test sections. Since then the number of states and test sections has steadily increased. Table 1 summarizes the SMA test projects constructed in the United States. through 1993. In 1994, the total tonnage of SMA mix projected to be placed in the United States was over 240,000 tons.

2.7 Development of United States SMA Guidelines

In the United States, guidelines for the selection of materials and the design and construction of SMA mixtures have been developed by a Technical Working Group (TWG) sponsored by the Federal Highway Administration and the National Asphalt Pavement Association. The SMA TWG is a panel of knowledgeable pavement engineers that was organized to provide guidelines for the transfer of the European SMA technology to the United States.

The SMA TWG has developed model specifications for the materials, design requirements, and construction of SMA pavements. Early versions of the model specifications attempted to duplicate, as closely as possible, the specifications used in Europe. However, this was not a simple task due to the fact that each of the European countries appeared to have unique requirements and often used different test methods. Since Germany and Sweden have the most SMA experience, their specifications were most often referenced. Also, many of the stabilizing additives were proprietary or

contractor "secrets". In the United States, it is not appropriate to specify particular products.

The development of the model specifications has therefore been an evolutionary process in which experience with the technology and materials in the United States has provided a basis for adjusting the requirements. The current version of the model specifications is divided into three areas: mix design, aggregate requirements, and construction guidelines. The specifications for each of these areas are presented in the respective chapters.

Table 1. U.S. SMA Test Sections and Projects Through 1993

YEAR	STATE	PROJECT LOCATION(S)	TONNAGE
1991	WISCONSIN	I - 94	1,000
	GEORGIA	I - 85	3,000
	MICHIGAN	M - 52	3,000
	MISSOURI	I - 75, St. Louis	1,000
1992	INDIANA	I - 70	1,000
	CALIFORNIA	I - 40	1,000
	ALASKA	SEWARDS HWY	4,000
	MARYLAND	US - 15 I - 70	10,000 25,000
	GEORGIA	I- 75	2,000
	NEW JERSEY	US - 1	4,000
	NEW YORK	Rt. 281	1,000
	MICHIGAN	I - 94	12,000
	MISSOURI	I - 70, Jefferson City	4,000
	OHIO	US - 33	16,000
	TEXAS	I - 35 / SH 171	8,000
	VIRGINIA	US - 29	2,000
	WISCONSIN	I - 43,	3,000
1993	ARKANSAS	I - 40	11,000
	CALIFORNIA	Rt. 152, Santa Clara	1,000
	GEORGIA	I - 95, Savannah	62,000
	ILLINOIS	I - 80 I - 57 I - 55 US - 24 US - 36 Rt. 121 Rt. 1 Lamont Rd.,	12,000 5,000 4,000 8,000 16,000 3,000 5,000 11,000
	KANSAS	US - 54	1,000
	MARYLAND	I - 95, Toll Rd. I - 83 I - 195 I - 695 I - 70	55,000 14,000 1,000 34,000 17,000

Table 1. continued

YEAR	STATE	PROJECT LOCATION(S)	TONNAGE
1993	MICHIGAN	I - 96 I - 94 US - 131	9,000 9,000 22,000
	MISSOURI	I - 70, St. Charles I - 70, Callaway I - 70, Saline	9,000 7,000 16,000
	NEBRASKA	Hwy 75	27,000
	NORTH CAROLINA	US - 264	2,000
	TEXAS	US - 79 US - 323 US - 60/83	5,000 7,000 1,000
	VIRGINIA	I - 66	10,000
	OHIO	US - 23, Sandusky I - 75, Findlay	60,000 20,000
	WISCONSIN	US- 51 US - 63 US - 45 I - 43	5,000 5,000 5,000 15,000

CHAPTER 3
REVIEW OF TESTING AND MIX DESIGN FOR SMA MIXTURES

3.1 Purpose of Mix Design

The design of any asphalt-aggregate mixture is basically the selection of material proportions to produce a mixture having certain desired properties or characteristics. Ideally, a mix design procedure should optimize component materials and proportions to yield a mixture that is resistant to all forms of distress which may reduce its performance in the pavement structure.

SMA mixtures are intended to be surface mixtures. Surface mixtures must obviously have good skid resistance. Rutting resistance of surface mixtures is also critical since the highest shear and compressive stresses occur at or near the pavement surface. Environmental elements (e.g., temperature changes, rain, sunlight, etc.) are also more active on the pavement surface, therefore, surface mixtures must be able to withstand these conditions. In other words, SMA mixtures must be resistant to polishing, rutting, thermal cracking, ravelling, moisture damage, and aging.

3.2 Current Methods of SMA Mix Design

In following with the European practice, the Marshall procedure has been used to design SMA mixtures in the United States. Current guidelines recommended by the SMA Technical Working Group [20] are as follows:

Design Procedure:

AASHTO T 245, Marshall Method (50 blows to each side of specimen)

Marshall Parameters:

Voids in Total Mix, percent	*3 - 4*
Voids in Mineral Aggregate, percent	*17 min.*
Stability, lbs.	*1400 min.*
Flow, 0.01 inch	*8 - 16*
Asphalt Content, percent:	*6 min*
Schnellenberg Draindown, percent:	*0.3 max.*

Gradation Range:

Sieve Designation	*Percent Passing*
3/4"	*100%*
1/2"	*85-95%*
3/8"	*60-75%*
No.4	*20-28%*
No.8	*16-24%*
No.30	*12-16%*
No.50	*12-15%*
No.200	*8-10%*

The Marshall method is also used by most states for the design of conventional dense-graded asphalt concrete mixtures. Therefore, it is a well known procedure and most agencies and contractors are equipped to perform the tests. Many states have successfully placed SMA mixtures that were designed by the Marshall procedure, although field adjustments in asphalt content have been common.

In 1992 and 1993, the Technical Working Group sponsored two round robin studies of the Marshall procedure with SMA mixtures. Ten laboratories participated in

the studies. Each laboratory used 50 blows per face with the standard Marshall hammer except for Payne & Dolan Inc. who used a rotating base and bevelled foot hammer. Optimum asphalt contents were selected at three percent air voids. Results of the round-robin studies are shown in Table 2. Notes from the TWG meeting [21] state that the variability of optimum asphalt content for SMA mixtures is significantly greater than for dense-graded mixtures.

Table 2. Results of the SMA TWG Sponsored Marshall Procedure Round Robin

	First Set				Second Set	
Agency	Asphalt Content (%)	VMA (%)	Stability (lbs)	Flow (.01 in)	Asphalt Content (%)	VMA (%)
Asphalt Institute	5.2	14.8	1800	10	7.0	20.6
Turner Fairbank	5.2	14.7	2350	13	6.4	19.4
FHWA OTA	5.2	15.0	2300	12	6.6	19.7
GA DOT	5.9	16.0	1650	10	6.9	20.2
MD DOT	5.2	15.0	1880	11	6.1	18.4
MI DOT	4.7	14.0	2300	9	5.9	18.3
MO DOT	4.5	13.5	1900	10	7.3	21.2
NCAT	5.9	16.1	1615	12	7.3	21.0
Payne & Dolan	4.9	13.9	2500	13	5.5	17.7
VA DOT	5.8	16.4	1610	11		
KY DOT					6.4	19.5

It is recognized that the Marshall procedure has several weaknesses. The mixture strength and deformation measures (stability and flow) are poorly correlated to performance and have generally been disregarded in SMA mix design. This is due

primarily to the impact compaction of the Marshall hammer which fails to orient the aggregate particles as does field compaction and create the aggregate structure which is important to SMA mixture strength. Therefore, the procedure is merely a volumetric exercise that is based on an inappropriate compaction method.

3.3 Review of Mix Tests for SMA

3.3.1 Drain-down Tests

A drain-down test is necessary to determine if the stabilizing additive is effective in mitigating run-off of the binder between production and placement of SMA mixtures. The Schnellenberg drain-down test, borrowed from Germany, was recommended in early versions of the model specifications [4]. The Schnellenberg drain-down test consists of pouring about 1000 grams of SMA mixture immediately after mixing at 150°C into an 800 ml glass beaker, then placing the beaker and mixture in an oven at 170°C for one hour. At one hour, the mixture is dumped out of the beaker without shaking or vibrating, and the weight loss of the mixture is determined. In 1993, the National Center for Asphalt Technology (NCAT) began development on an alternate procedure [20]. The NCAT drain-down test utilizes a cylindrical wire basket rather than a beaker to contain the mixture while in the oven. The advantage of this procedure is that the drained binder drips out of the container which makes determination of the weight loss more straight forward.

3.3.2 Uniaxial Creep Tests

A few research studies have utilized uniaxial creep (i.e. static load) tests to characterize permanent deformation potential of SMA mixtures. Little [22] used an

unconfined uniaxial creep test to evaluate field cores from Georgia's first SMA project. Tests were performed at 40°C with axial stress levels of 20, 70, and 100 psi for one hour. Using criteria developed in the Asphalt-Aggregate Mixture Analysis System (AAMAS) study [23], Little concluded that the SMA mixtures had excellent resistance to deformation. He added that the test was very demanding for an SMA mixture, and that confinement would substantially improve the creep response.

In a separate study [24], Little used the creep test to evaluate laboratory prepared SMA mixtures. Four inch diameter by eight inch high specimens were prepared using a kneading compactor. The compactive effort was selected to produce specimens with approximately four to five percent air voids. In this study, samples were tested unconfined and with 30 psi confining pressure. In the unconfined state, an axial stress of 20 psi was applied; for the confined tests the creep load was 50 psi. All tests were performed at 40°C. In both cases, samples containing a low density polyethylene (LDPE) modified asphalt and polyester fibers performed well, whereas samples with only fibers failed.

Brown [25] and Brown and Manglorkar [26] also used confined creep tests, but using different conditions. Using samples compacted in the Gyratory Testing Machine, creep tests were performed at 60°C with 20 psi confining pressure and 100 psi axial deviator stress. Several SMA mixtures were evaluated with variations in asphalt content, fiber type and content, filler content, and percent passing the No.4 sieve. Results indicated that the mixtures were more resistant to deformation at lower asphalt contents, at fiber contents between 0.2 and 0.3 percent, and at fines contents (% passing No.4)

around 30 percent. Optimum filler contents were dependent on each mixture. No particular fiber type appeared to be superior based on the creep test results.

3.3.3 Repetitive Uniaxial Tests

Several research projects have also used repeated-load uniaxial tests. Brown and Manglorkar [26] used a repeated-load sequence as a modification to the confined, uniaxial, creep test. Test conditions were the same as used in their creep tests (20 psi confining stress, 100 psi deviator stress, and 60°C) except that repeated loads were applied using a haversine waveform over 0.1 second followed by 0.9 seconds unload. Repeated-loads were applied for 3600 cycles, then the sample was allowed to recover for 15 minutes. The repeated load condition was much more severe than the static-load condition. Accumulated permanent deformations were generally 2 to 3 times greater than for the static creep tests. The repetitive load tests showed more sensitivity to asphalt content, but less sensitivity to filler content, fiber content, and fines content.

Svec and Veizer [27] performed repeated uniaxial tests on SMA mixtures containing various percentages of ground tire rubber. They used Marshall specimens in an unconfined state. Loading was applied with a square wave with maximum stress of 100 psi for 0.2 seconds followed by 1.8 seconds rest. Tests were performed at 25 and 40°C. Based on the accumulated permanent strains and the slopes of the permanent deformation versus cycles plots, they concluded that five to ten percent rubber by weight of asphalt cement was the optimum dosage.

3.3.4 Loaded Wheel Tests

The Georgia Loaded Wheel Tester (GLWT) was used by FHWA's Turner-Fairbank Highway Research Center [28,29] and the Georgia Department of Transportation [30,31] to evaluate the rutting resistance of SMA mixtures. The FHWA studies included tests with the GLWT and the French Pavement Rutting Tester to evaluate the effects of different stabilizers [29] and to compare SMA mixtures to dense-graded mixtures [28]. The study to evaluate the stabilizers concluded that the laboratory prepared SMA mixtures had good rutting resistance in both wheel rutting devices and that the results were not significantly different for the different stabilizers. Likewise, in the study comparing DGAC mixtures to SMA mixtures, the results with both devices indicated that all mixtures were rut resistant and that no statistical difference was evident between the DGAC mixtures and the SMA mixtures.

The Georgia DOT also used the GLWT to test plant-produced mixtures and cores from their first two SMA projects. On the first project, three SMA mixtures and two conventional mixtures were tested. Although the GLWT results indicated that all five mixtures were very resistant to rutting, the SMA mixtures were clearly superior [30]. On the second SMA project, plant mix and cores of both conventional DGAC and SMA mixtures were again tested. Both mixture types again were very resistant to rutting, but for this project, the GLWT rut depths for the SMA mixture were slightly greater than for the conventional mixture [31].

3.3.5 Gyratory Tests

Compaction characteristics of SMA mixtures using gyratory-type machines have been evaluated by several researchers. Brown and Manglorkar at NCAT [26] used several tests including the Corps of Engineers Gyratory Testing Machine (GTM) to study the effects of variations in component proportions in SMA mixtures. This study utilized a GTM equipped with an oil-filled roller, and samples were compacted to 75 revolutions with a vertical pressure of 120 psi and a one-degree angle of gyration. Three GTM parameters were evaluated for each sample: Gyratory Shear Index (GSI), Gyratory Elasto-Plastic Index (GEPI), and the shear stress produced at a one degree angle. GSI results indicated that all mixtures were very stable regardless of variations in asphalt content, filler content, fine aggregate content, and fiber type. Likewise, no relationships or trends were evident between GEPI and mixture proportions. Gyratory shear strength produced at a one-degree angle was found to be more sensitive. Results indicated that increasing the asphalt content reduced shear strength slightly, but the small strength loss was evidence that the SMA mixtures were highly tolerant to changes in asphalt content. The effect of changes in fiber type, fiber content, and mineral filler content on shear strength was found to be dependent on the type of aggregate used in the mixtures.

The two FHWA studies by Stuart et al. [28,29] also used the Corps of Engineers GTM to compare the effects of stabilizers on SMA properties and to compare DGAC mixtures with SMA mixtures. The stabilizer study [29] used a 1993 proposed revision to ASTM D 3387 which employs an oil-filled roller, a vertical pressure of 120 psi, and a 0.8 degree angle of gyration. Samples were compacted to refusal density which is defined as

the point where the change in density decreases to less than 16 kg/m^3 per 100 revolutions. This typically required between 260 and 300 revolutions. Shear strength, GSI, and GEPI were measured. All three gyratory parameters for each mixture containing different stabilizers were found to be statistically equal. It was also found that the three parameters were not significantly affected by change in binder content. This was interpreted as an indication that binder contents higher than designed by the Marshall procedure could be used without detrimentally affecting rutting resistance.

The study comparing DGAC mixtures with SMA mixtures [28] used a slightly different procedure. The report states that the mixtures were tested at 60°C in accordance with the National Cooperative Highway Research Program (NCHRP) Asphalt-Aggregate Mixture Analysis System (AAMAS) procedure [23]. Specimens were tested in the GTM with an oil roller using 120 psi vertical pressure and a one-degree angle. Samples were compacted to 300 revolutions. Gyratory Stability Index (GSI) and refusal density were reported for each mixture. The study concludes that GSI values for the DGAC mixtures and the SMA mixtures were statistically equal and that all of the mixtures were resistant to rutting. Refusal air voids were lower in the SMA mixtures than with the DGAC mixtures. Extractions were also performed on the tested samples to compare aggregate breakdown in the GTM to the Marshall hammer. These data indicated that the breakdown caused by the above GTM procedure was nearly identical to the breakdown caused by the 50-blow Marshall compactive effort.

Little [24] used several types of compaction including the Texas gyratory compactor in a study to evaluate characteristics of SMA mixtures. Also evaluated were

kneading compaction and 50-blow Marshall compaction. Results showed that at equal asphalt contents, the Texas gyratory produced the lowest air voids, followed by kneading compaction and then Marshall compaction. However, the low air void content gyratory samples produced the highest Hveem stabilities, which according to Little indicated that when the high binder content SMA mixtures were compacted to ultimate densification (such as with the Texas gyratory) the mixtures did not suffer a loss of strength. He added that the gyratory compactor apparently produces a better interparticle matrix of the coarse aggregate for load distribution than the kneading compactor.

3.3.6 Resilient Modulus Tests

Diametral resilient modulus tests have been performed on SMA mixtures by several researchers. Generally, most researchers have followed the resilient modulus procedure ASTM D 4123. Little [22] used the resilient modulus test in the evaluation of the SMA mixtures used in Georgia's first SMA project. Using cores taken from the Georgia SMA test sections, modulus values were determined at three temperatures: 0, 25, and 40°C. These results indicated that the stiffness of the SMA cores tended toward the low end of the modulus range typical of DGAC mixtures. At 40°C, the resilient moduli of the SMA cores were actually slightly below the range for dense graded mixtures. This prompted Little to postulate that diametral testing of SMA mixtures may not be appropriate at higher temperatures. Little also evaluated other tensile properties such as creep moduli, tensile strength, and strain at failure. He used the resilient modulus data together with the strain at failure to evaluate fatigue response using a technique from the

AAMAS procedure [23]. This evaluation led him to conclude that the SMA mixtures had a favorable fatigue response which was consistent with the concept of using a rich binder mastic.

In another report [24], Little used the diametral resilient modulus to demonstrate the effects of a low density polyethylene (LDPE) additive on tensile stiffness of an SMA mixture. His data showed a significant increase in mixture stiffness at 25 and 40°C when 4.5% LDPE was added to the binder. Another interesting note about his results was that the binder content did not appear to effect the moduli of mixtures containing a 0.15% polyester fiber alone, but when the fiber and LDPE were added together, the stiffness peaked at 5.5% binder content.

Brown and Manglorkar [26] also included diametral resilient modulus testing in their research to evaluate variations in mix proportions. They found no consistent correlations between moduli and fiber content, dust content, fine aggregate content, or asphalt content. The lack of any significant trends was attributed to high variability of the test. SMA mixtures prepared with a granite aggregate typically had moduli approximately equal to that of dense-graded mixtures; whereas those containing a gravel aggregate had moduli lower than typical dense-graded mixtures.

Stuart and Mogawer's comparison of DGAC and SMA mixtures [28] included the resilient modulus test to evaluating several mixture characteristics. They performed resilient modulus tests on DGAC and SMA mixtures at 10 different temperatures ranging from -32°C to 40°C. For the test mixtures with 12.5 mm top-size aggregate, the moduli of the SMA was lower than for the DGAC. For mixtures with 9.5 mm top-size aggregate,

moduli were statistically equal for SMA and DGAC mixtures. Resilient moduli of mixtures before and after moisture conditioning were also evaluated to assess moisture damage potential. This analysis indicated that the SMA mixtures were less susceptible to moisture damage than the DGAC mixtures. Resilient modulus ratios for the SMA mixtures were greater than 70 percent; whereas resilient modulus ratios for the DGAC mixtures were below 70 percent. These conclusions were also confirmed by tensile strength tests. This same type of analysis was also performed to evaluate changes occurring upon aging in accordance with the procedures recommended from the Strategic Highway Research Program. The conclusions from this part of the study was that tensile strength and stiffness of SMA mixtures increased significantly less than DGAC mixtures due to aging, which indicated that SMA mixtures would be more resistant to cracking after aging.

3.3.7 Tensile Strength Tests

Indirect tensile strength has also been used by many researchers to evaluate SMA mixtures. Most researchers have measured indirect tensile strength at 25°C using a vertical deformation rate of 2 inches per minute.

Brown and Manglorkar [26] found that tensile strengths of SMA mixtures were lower than DGAC mixtures. Increasing the asphalt content and filler content of SMA mixtures did result in a gradual increase in tensile strengths. Likewise, shifting the gradation toward the maximum density line (increasing the percentage passing the No. 4

sieve) also increased the tensile strength. Fiber content and fiber type, however, did not appear to have a significant effect on tensile strength.

Little [24] used the indirect tensile strength and the strain (horizontal) at failure to evaluate several mixtures. He found that LDPE and fibers added to an SMA mixture substantially increased tensile strength but no statistical difference was evident in strain at failure. He also measured tensile strengths and strains at failure at 25°C using a deformation rate of 0.5 inches per minute and found the same trends. Compared to typical DGAC mixtures, Little concluded that SMA mixtures had about the same tensile strength, but higher strains at failure. However, he also made several precautionary comments on the use of the indirect tensile testing mode for SMA mixtures, stating that "this type of testing may not be indicative of the relative response of SMA mixtures to traditional densely graded mixtures in the field...Probably the most effective use of the IDT (indirect tensile) test is to simply compare candidate SMA mixtures and not to compare the results of SMA and densely graded mixtures."

The indirect tensile test has also been used to evaluate moisture damage potential of SMA mixtures by several researchers. This type of evaluation typically consists of comparing the tensile strengths of two sets of samples: one set conditioned by water saturation, soaking in a 60°C temperature bath and then, in some cases, one or more freeze-thaw cycles, the other set unconditioned. Standardized procedures for this test are AASHTO T-283 and ASTM D 4867. The Georgia DOT used this procedure on plant mix and roadway cores from their first two projects and reported acceptable results for each of the SMA mixtures [30,31].

3.3.8 Diametral Creep

Diametral creep, also known as indirect tensile creep, was measured by Little [22,24] on cores from the first Georgia SMA project and on laboratory prepared samples. Results on the cores, apparently at low test temperatures, showed that the SMA mixtures deformed more than typical dense-graded mixtures which indicated a greater ability of the SMA mixtures to relax and shed tensile stresses during a decrease of pavement temperature. The laboratory prepared samples were tested at warmer temperatures and used to evaluate relative differences in fatigue resistance. Little concluded that the SMA mixtures are more resistant to fracture and crack propagation than typical dense-graded mixtures. He also stated that polymer modification was necessary to keep tensile strains at a reasonable level to reduce accumulated damage due to distortion [24].

CHAPTER 4
TESTING PROGRAM

4.1 Introduction

There are several reasons to develop an improved procedure for SMA mix design. The Marshall procedure, although it is familiar, has some deficiencies including hammer compaction, high variability, and probably most significant, it lacks a measure of deformation resistance. The recipe based formulation of SMA mixtures may provide some assurance based on historical performance, but this can also be restrictive to alternative component blends which may perform better or be more economical. Mix design should include tests that indicate which materials and combinations are superior in terms of deformation resistance, cracking resistance, and moisture damage resistance. The testing program for this study was set up to identify a set of test methods which better represent the important mixture placement and distress conditions which exist in the field.

4.2 Selection of Tests

Selection of the tests to be evaluated for potential use in SMA mix design was based on a variety of factors. It was desired to have at least one test to evaluate each of the major forms of pavement distress. It was important that the test simulate field conditions and have some history in correlating to actual field performance, preferably with SMA mixtures. It was not an objective of this study to develop new mixture tests.

From a general review of recent literature, some of the most promising performance related test procedures were identified. Many of the tests were identified from the SMA literature review presented in the previous section. Other promising tests had been used for evaluation of dense-graded asphalt mixtures, but had not yet been used for testing of SMA mixtures.

The final factor, or constraint, used to select tests for this project was equipment availability. Funding for this research project did not include any funds for the purchase of equipment or for subcontracting tests to other laboratories. Therefore, it had to be possible to perform the selected tests with equipment available at the University of Florida Civil Engineering laboratories or the Florida Department of Transportation's Central Bituminous Laboratory or Bituminous Research Laboratory.

The selected tests, categorized by distress mode, are shown in Table 3. Three tests were selected to characterize rutting potential: the GTM densification/shear test, the Georgia loaded wheel test, and the triaxial repeated-load test. This redundancy was felt to be beneficial considering the possibility that one of the tests may not be representative of actual performance, or if all three tests were satisfactory, it would allow other agencies to determine rutting resistance of SMA mixtures with only one test device. To provide an indication of fatigue resistance, two tests were selected: the indirect tensile strength test and the resilient modulus test. For evaluation of low temperature or thermal cracking, the diametral creep compliance and low temperature resilient modulus tests were chosen. And for evaluation of moisture damage, the wet/dry indirect tensile strength and resilient moduli tests were selected.

Table 3. Selected Mixture Tests

Distress	Test	References
Rutting	GTM Densification/Shear Georgia Loaded Wheel Tester Triaxial Repeated Load	Ruth et al [32] Lai [33], West et al. [34] Brown [26], Gabrielson [35]
Fatigue Cracking	Indirect Tensile Strength & Strain Resilient Modulus	Von Quintus et al. [23]
Thermal Cracking	Diametral Creep Low Temperature Resilient Modulus	Von Quintus et al. [23]
Moisture Damage	Wet/Dry Resilient Modulus Wet/Dry Indirect Tensile Strength	Von Quintus et al. [23] AASHTO T 283 [36], ASTM D 4123[37]

Compaction of all test specimens, except for the Georgia Loaded Wheel test beams, was accomplished with the Corps of Engineers Gyratory Testing Machine (GTM). The GTM compactive effort was adjusted by using different numbers of gyrations so that the air void content of the compacted samples were as close as possible to the average in-place air void content for each particular mixture. For experimental mixtures that did not have any field data, a standard compactive effort was used that had been selected from the data generated from the mixtures with field data.

A flow chart showing the general order of testing and number of specimens per test is shown in Figure 5. As indicated, test specimens were often used for more than one test. This was possible due to the fact that some tests were non-destructive to the samples. This permitted a significant reduction in the material and sample preparation time. Utilizing the available materials as efficiently as possible was important since much of the material was obtained and shipped free of charge by other state highway agencies and paving contractors. For experimental mixtures, which utilized the standard

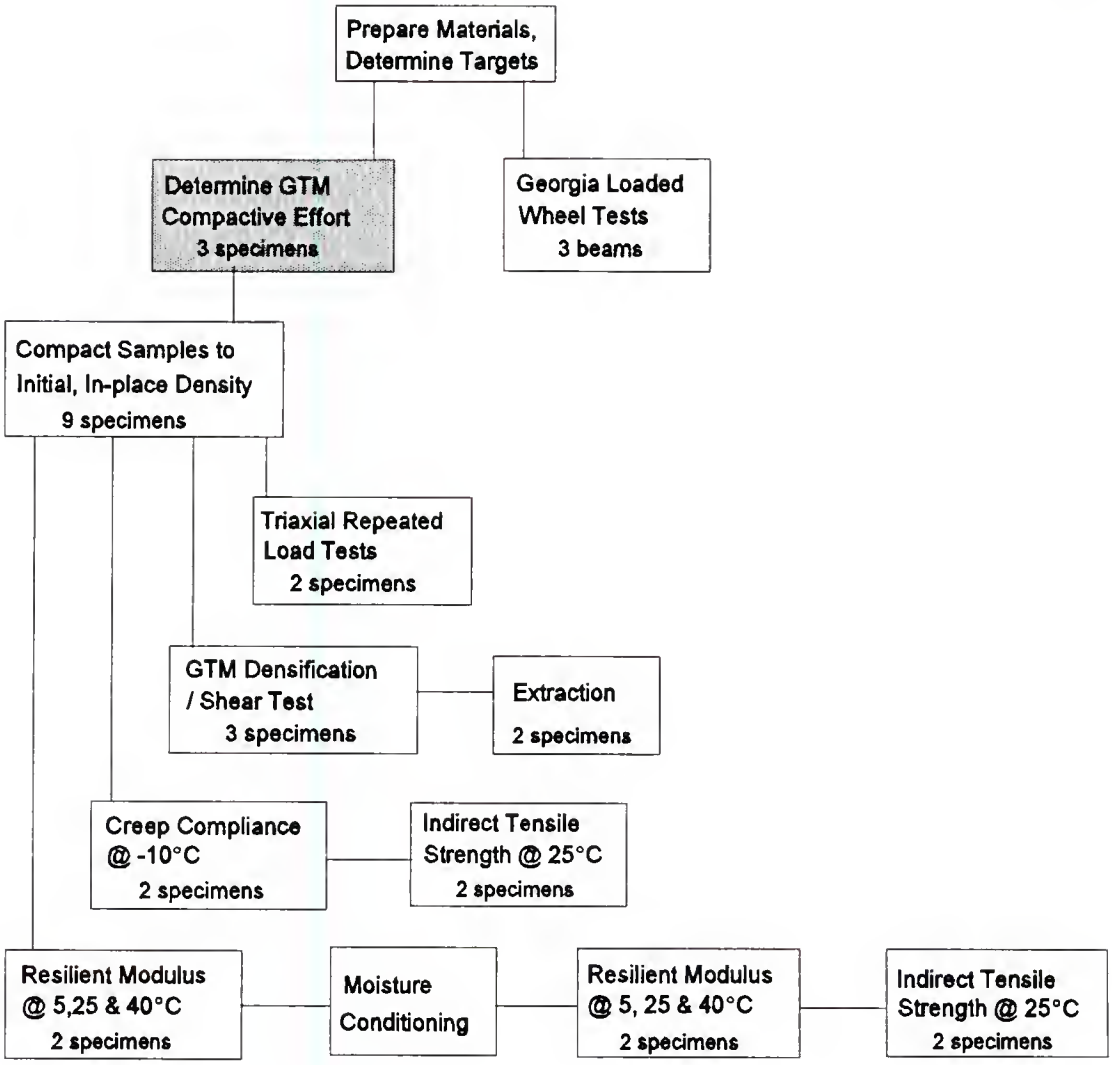
Prepare Materials, Determine Targets
Determine GTM Compactive Effort 3 specimens
Georgia Loaded Wheel Tests 3 beams
Compact Samples to Initial, In-place Density 9 specimens
Triaxial Repeated Load Tests 2 specimens
GTM Densification / Shear Test 3 specimens
Extraction 2 specimens
Creep Compliance @ -10°C 2 specimens
Indirect Tensile Strength @ 25°C 2 specimens
Resilient Modulus @ 5,25 & 40°C 2 specimens
Moisture Conditioning
Resilient Modulus @ 5, 25 & 40°C 2 specimens
Indirect Tensile Strength @ 25°C 2 specimens

Figure 5. Flow Chart of Testing Sequence

compactive effort, the step where the compactive effort is determined (shown as the shaded box) was eliminated.

CHAPTER 5
MATERIALS AND TEST PROCEDURES

5.1 Materials

5.1.1 SMA Mixtures from Field Projects

Material components for some of the early SMA mixtures placed in the U.S. were obtained in cooperation with several highway agencies and paving contractors. SMA mixtures from eleven field test sections were duplicated in this study.

For each mixture, the average of the field construction data (gradation, binder content, and in-place density) was used as the target for preparing the laboratory test samples. Table 4 includes descriptions of the components and the field data used to prepare the laboratory mixtures. Complete descriptions of each mixture are included in Appendix A.

For the purpose of identification, each mixture was given a "Mix I.D." which includes the state abbreviation for easy recognition. For states that have had several SMA mixtures placed, the number following the state abbreviation should correspond to the chronologic order in which each mix was placed.

GA1. This is a coarse SMA mixture that was used as a binder layer on Georgia's first SMA project which was placed in late July 1991 on Interstate 85 northeast of Atlanta [30]. The mixture contains a granite coarse aggregate (Buford mine), and a mastic

Table 4. Materials from SMA Field Projects

Mix I.D.	GA1	GA2	GA3	GA4	WI1	WI2	WI3	WI4	MD1	TX1	VA1
Location	I-85	I-85	I-85	I-75	I-94	I-43	Ryan Rd.	US 45	US 15	I-35	US 29
Materials	50% #6 20% #7 13% #89 5% SCR 11% MF 1% Lime Novophalt Inorphil	47% #7 29% #89 12% W-10 11% MF 1% Lime AC-30 Novophalt Inorphil	35% #7 39% #89 15% SCR 10% MF 1% Lime AC-30 Novophalt Inorphil	46% #7 30% #89 15% #777 8% MF 1% Lime AC-20 Sp Styrelf Cellulose	33% 1/2" 35% 3/8" 25% SCR 7% MF 85-100 Vestoplast	45% 3/8" 33% 1/4" 12% M Snd 10% MF 85-100 Vestoplast	65% 3/8" 15% 1/4" 10% M Snd 10% MF MAC 10	25% 5/8" 54% 7/16" 12% M Snd 9% MF 85-100 Inorg. fiber	43% #68 35% #8 11% SCR 11%Ag.lime AC-20 Vestoplast	30% Gr. 3 43% Ty. D 14% Gr. 4 13% MF AC-20 Perma-Tac Arbocel	60% 3/4-3/8 23% 3/8-#4 16% Ag.lime 1% Lime AC-20 Arbocel
AVERAGE FIELD RESULTS											
Sieve	Percent Passing										
3/4"	100	100	100	100	100	100	100	100	100	100	100
1/2"	64	99	99	99	94	100	100	91	89	89	85
3/8"	39	85	83	79	69	96	96	77	71	65	63
#4		45	38	39	28	36	36	26	31	29	28
#8	22	29	24	25	20	22	24	19	18	15[1]	20
#16					16	18	19	16	15		
#30					14	16	17	15	14		17
#50	18	19	16	15	13	15	16	12	13	14[2]	16
#100					12	14	15	10	12	13[3]	15
#200	10.0	10.0	10.1	8.0	10.0	12.3	12.9	9.2	9.6	10.1	12.0
%AC	5.7	5.5	5.6	5.9	5.5	5.5	6.7	5.9	6.2	6.4	6.2
Air Voids (%)	5.0	7.0	6.3	5.7	6.8	10.5	7.6	6.5	5.9	7.0	7.3

[1] % Pass #10 sieve, [2] % Pass #40 sieve, [3] % Pass #80 sieve.

consisting of a marble dust mineral, filler mineral fibers, and an AC-20 modified with 5% low density polyethylene (LDPE). This mixture is unique among the other mixtures included in this study due to its gradation and its use as a binder layer. The top size aggregate used in this mixture was ½ inches. Although specific performance data is not available on this mixture due to its location in the pavement structure, the pavement as a whole is performing very well.

GA2. This mixture contains the same component materials as GA1, but has a much finer aggregate gradation [30]. The top size aggregate used in this mixture was ⅜ inches. This mixture, placed on Georgia's first SMA project in September 1991, was used as a surface layer. The available performance data (Table 5) shows that the section is performing very well with very low rut depths and excellent skid test results.

Table 5. Performance Data for GA2

Date (Age)	April, 1993 (1.6 years)	June, 1994 (2.75 years)
Average Rut Depth (inches)	0.01	0.09
Average Friction Number	52	not available
Average Air Void Content (%)	7.3	5.8

GA3. This is the third SMA mixture placed on Georgia's first SMA project [30]. This mixture contains a different granite aggregate (Ruby mine) which has a lower LA abrasion value than the Buford granite. Compared to GA2, the gradation of GA3 is coarser on the No.4 through the No.100 sieve. Like GA1 and GA2, this mixture also contains marble dust mineral filler, mineral fibers, and AC-20 modified with 5% LDPE. This mixture was also used as a surface layer. The available data (Table 6) shows that this

section is also performing very well. Rut depths are practically negligible and skid test results are very good.

Table 6. Performance Data for GA3

Date (Age)	April, 1993 (1.6 years)	June, 1994 (2.75 years)
Average Rut Depth (inches)	0.05	0.09
Average Friction Number	48	not available
Average Air Void Content (%)	7.6	8.0

GA4. This SMA mixture was placed on Georgia's second SMA project which was constructed on Interstate 75 south of Atlanta in 1992 [31]. Granite aggregates from mines in Tyrone and Mt. View, Georgia were used in this mixture. The LA abrasion values for the Tyrone and Mt. View granites were 41 and 37, respectively, which are well above the recommended maximum limit of 30, and are believed to be the highest used in an SMA project to date. The gradation for the GA4 mixture was nearly identical to that used in GA3. The mixture also contains marble dust mineral filler, domestic cellulose fibers, and an SBS modified AC-20 special. A thin overlay was placed over this project in late 1992 due to motorists overreacting to the change in surface texture of an adjacent test section. There were no signs of distress in the SMA or other sections at the time of the overlay. Consequently, no performance data was available for this section during preparation of this dissertation.

WI1. This SMA mixture is from the first SMA test section constructed in the U.S. which was placed on Interstate 94 near Waukesha, Wisconsin in July 1991. The mixture contains specially screened limestone aggregates from East Quarry, limestone dust

filler, and an 85-100 penetration asphalt. A pelletized polyolefin was added as a stabilizing agent. The gradation of this SMA mixture is one of the few included in this study which meets the TWG's recommended gradation band. Brown [1] reported that flushing had occurred in an area where a vibratory roller was used. Early friction test results showed that the SMA had lower skid numbers than the adjacent conventional mixture. Recent discussions with Wisconsin DOT personnel indicate that the test section is performing well. No other performance data was available.

WI2. The second SMA mixture from Wisconsin was placed on Interstate 43 in Waukesha County during August, 1992. This mixture contains specially screened limestone aggregates from Crowbar quarry, a limestone dust mineral filler, and an 85-100 pen asphalt. Several test sections were constructed with this base mixture. Each section contains a different stabilizing additive. The mixture from the section containing 7% polyolefin additive was duplicated in this study. A unique feature of this mixture is that the gradation has a ⅜ inch top size rather than a ½ inch top size. Construction data indicate that this mixture had high in-place pavement air voids. The average in-place air void content for this SMA pavement was 10.5 percent, whereas most other SMA pavements in the U.S. have had initial air void contents in the range of 5.5 to 8.0 percent. Post construction performance of this pavement has not been reported.

WI3. This SMA mixture was placed on Ryan Road in the Milwaukee area during September 1993. Specially screened limestone aggregates from Franklin quarry, limestone dust filler, and a polymer modified AC-10 were used in this mixture. The gradation of this

mixture was very near the same as used in WI2. No performance information has been reported for this SMA section.

WI4. This SMA mixture, which was also placed in September 1993, was used on a project in Three Lakes, Wisconsin on US 45. This mixture contains a crushed gravel aggregate from Consolidated mine. A limestone dust was used for the mineral filler, and the binder was a 85-100 pen asphalt. Six test sections, each with different stabilizing additives, were constructed on the project. Only the mixture using inorganic fibers was duplicated in this study since the construction data showed that this mixture had the least variation during production.

VA1. This SMA mixture was placed on a project on US 29 in Lynchburg, Virginia in the fall of 1992 [38]. This mixture contains specially screened aggregates quarried from an anorthosite traprock. Agricultural lime from an argillaceous marble was used as the fine aggregate and mineral filler. AC-20 was used as the binder. Two SMA sections were placed on the project: one containing polyolefin and the other containing cellulose fibers. The mixture containing cellulose fibers was duplicated in this study. In August 1993, flushing of the binder to the pavement surface was observed in isolated areas of both sections. A brief investigation [39] indicated that the mixtures were close to the job-mix-formulas and no definitive reason could be given for the flushing. Despite the flushing, no rutting had occurred in the SMA sections.

MD1. This SMA mixture was placed on US 15 in Frederick, Maryland during 1992. The coarse aggregate in this mixture is a gabbro obtained from Virginia. A small percentage of limestone was used for fine aggregate, and agricultural lime was used for

mineral filler. Test sections were constructed with cellulose fiber and polyolefin stabilizing additives. The mixture containing the polyolefin additive was evaluated in this study. Shortly after the sections were constructed, the surface of the cellulose section appeared "tight" or seemed to have less texture. However, no rutting was reported. More recent discussions with Maryland DOT personnel indicates that the SMA sections are performing well. No performance measurements have been reported.

TX1. This SMA mixture was placed in August 1992 on the business loop of Interstate 35 in Alvarado, Texas [40]. The mixture was also placed on Texas State Highway 171 near Cleburne. Components of the mixture were limestone coarse aggregate, limestone dust mineral filler, AC-20, and pelletized cellulose fibers. The gradation of this mixture was within the range recommended by the SMA TWG. Discussions with Texas DOT personnel indicate that the SMA is performing well. No measured performance data is available.

Field performance. In general, all of the SMA mixtures obtained from other states have performed well in the field. Some states have reported isolated areas of flushing of the mastic to the pavement surface, but in each case the flushing was not associated with any rutting. At the time this dissertation was prepared, very little performance data was available. Several of the mixtures included in this study have been in service for over three years.

5.1.2 Experimental SMA Mixtures with Florida Aggregates

It was necessary to include in the study aggregates that are available within the state of Florida to evaluate their potential for use in SMA mixtures. Six sources of coarse aggregate were selected representing the range of properties for materials currently used in asphalt mixtures in Florida. An attempt was made to include aggregates covering the geologic and geographic areas of the state. Brief descriptions of the selected coarse aggregates are given below. Each description includes a Mix I.D. to simplify identification. The order of the I.D. numbers is not significant; the mixtures were simply numbered in the order that they were tested.

FL1. Limestone aggregates from Dade County (FDOT mine no. 87-339) were used in this mixture. This and other similar aggregates mined from the Fort Thompson and Miami Limestone Formations in Dade County are widely used as construction aggregates in southeast Florida and along the east coast of the state. This aggregate possesses unique wear characteristics due to the significant silica content of this limestone formation. Therefore, it is used extensively for friction course mixtures throughout the peninsula. The aggregate tends to be chalky and typically has an LA abrasion value of 31, and water absorption of about 3 percent.

FL2. This mixture contains limestone aggregates mined from the Ocala and Suwannee Limestones in Hernando County (FDOT mine no. 08-012). This aggregate is considered typical of the relatively pure limestones mined from the east-central part of the state. It has been widely used in asphalt mixtures in central Florida for many years. LA

abrasion for this aggregate is typically about 36, and water absorption is about 2.3 percent. This aggregate also tends to be chalky.

FL3. This mixture contains a dolomitic limestone coarse aggregate mined from the Ocala and Suwannee formations in Taylor County (FDOT mine no. 38-268). This aggregate source is one of the few limestone mines in the northern part of the state. LA abrasion for this aggregate is usually around 40, and water absorption about 2.7 percent. The aggregate contains more porous particles than the calcium carbonates from mid and south Florida. It is presently considered as marginal in quality relative to the other aggregates mined in the state.

FL4. This mixture contains aggregate derived from a crushed concrete pavement taken from Interstate 75 in Hillsborough County. This crushing operation was given FDOT mine no.13-395 in 1991. LA abrasion for this crushed concrete aggregate has averaged around 48, and water absorption is about 5.1 percent. Based on these test results this aggregate would be considered poor quality. However, it is apparently being used successfully in conventional asphalt mixtures.

FL5. The aggregate used in this mixture is from a dolomitic limestone quarry in the Newala Formation in Shelby County, Alabama (FDOT mine no. AL-149). This aggregate is included in the study because it is commonly used in asphalt mixtures in the panhandle of the state. It typically has an LA abrasion value of 23, and water absorption around 1.0 percent. This dolomitic limestone is considerably denser and harder than the Florida limestones.

FL6. This mixture contains crushed river gravel aggregates obtained from deposits along the Chattahoochee River in Gadsden County (FDOT mine no. 50-120). This mostly quartz gravel is mined from the Citronelle formation. This is the only FDOT approved, non-limestone source of coarse aggregate within the state. It has been widely used for asphalt mixtures in the central part of the panhandle. Due to its polish resistance, it was also used as a coarse aggregate in open-graded friction course mixtures for over ten years. It was disallowed in this application in 1993 due to problems with ravelling. This aggregate typically has an LA abrasion value of 41, and water absorption of about 0.4 percent.

Other components of experimental mixtures. In order to evaluate the differences in mixture characteristics which were due only to the aggregates, the gradation and the other mix components were kept constant.

The gradation used for all experimental mixtures, shown in Table 7, was near the middle of the gradation range of the early versions of the FHWA's model SMA specifications [4]. This gradation is similar to that used in mixture WI1. In July 1993, the range for passing the No. 4 sieve was adjusted to 20 - 28 percent by the TWG [20]. Therefore, the gradation of the experimental mixtures is slightly above the current recommended range at the No. 4 sieve.

Generally, to meet this gradation with the different aggregates, it was necessary to fabricate the samples by adjusting the gradations of the components. Complete descriptions of the aggregate components and batch sheets are given in Appendix B.

Table 7. Gradation Used For Experimental SMA Mixtures

Sieve	Gradation (Percent Passing)	TWG Spec. Range
3/4 (19.0 mm)	100	100
1/2 (12.5 mm)	95	85 - 95
3/8 (9.5 mm)	70	60 - 75
No.4 (4.75 mm)	30	20 - 28
No.10 (2.0 mm)	20	15 - 23*
No.40 (425 µm)	14	12 - 15.5*
No.80 (180 µm)	11	10 - 13*
No.200 (75 µm)	9	8 - 10

*Interpolated from Standard Sieves

The mineral filler used in the experimental mixtures is a marble dust, known as R04, obtained from Georgia Marble Co. in Marble Hill, GA. This is the same filler that was used in all of the Georgia SMA mixtures tested in this study. Characteristics of this mineral filler are given in Table 8.

The asphalt cement selected for the experimental mixtures was an AC-30 from Coastal Fuels' terminal in Jacksonville. Forty gallons of this asphalt were obtained on September 14, 1992. This asphalt was tested according to the SHRP binder specifications and graded as a PG 64 - 22.

Cellulose fibers and FDOT Type A ground tire rubber were used as stabilizing additives in the experimental mixtures. Cellulose fibers, CF31005, from Custom Fibers Inc. were added at a dosage of 0.3 percent by weight of total mix. The ground tire rubber (GTR) was blended with the asphalt cement at a dosage of 12.0 percent by weight of

Table 8. Mineral Filler Properties

Composition	$Mg,CaCO_3$ 95% min.	Hydrometer Analysis	
Acid Insolubles	3% max.	Grain Diameter (mm)	Percent Finer
pH	9.0-9.5	.075	99
Specific Gravity	2.710	.034	47
Sieve Analysis		.022	31
		.013	20
Sieve (Opening)	Percent Passing	.010	13
No.40 (.425mm)	100	.007	10
No.80 (.180mm)	95	.003	5
No. 200 (.075mm)	71	.001	2

asphalt cement. Half gallon quantities of GTR and asphalt were preblended at about 325°F with a high speed paddle mixer for about five minutes to achieve uniform dispersion and reaction of the rubber and asphalt.

5.2 Test Procedures

5.2.1 GTM Compaction

Gyratory compaction was selected based on several studies which have shown that this mode of compaction best simulates field compaction by rollers in terms of the resulting density, particle orientation, and engineering properties of the compacted samples [23]. Although these studies were performed using traditional dense-graded mixtures, it is presumed that the conclusions apply to SMA mixtures as well. Due to the stone-on-stone aggregate structure, particle orientation may, in fact, be more important.

For this research, a gyratory compaction procedure initially developed by Ruth and Schuab [41] was used. This procedure, which utilizes a GTM equipped with an air roller (Figure 6), is intended to compact the samples to the initial in-place density following construction, typically between 92 and 94 percent of the theoretical maximum density. The settings used to achieve this level of compaction with the GTM Model 6B/4C are 100 psi ram pressure, 3 degree initial angle of gyration, and 9 psi initial air roller pressure. Work by Ruth et al. [32] determined that 18 gyrations generally produced the desired density for many dense-graded mixtures. To establish the compactive effort necessary for the SMA mixtures in this study, compaction curves were developed for each mixture.

Three samples for each mixture were prepared and compacted in the GTM to determine the number of gyrations necessary to achieve the average initial in-place density. Each sample was compacted to a different number of gyrations. Sample heights, recorded with each gyration, and the bulk specific gravity of the sample measured following compaction were used to backcalculate densities at intermediate numbers of gyrations using Equation 1.

$$Gmb_x = Gmb_f \left(\frac{h_f}{h_x}\right) \quad (1)$$

where:

Gmb_x = bulk specific gravity of compacted mixture at x gyrations
Gmb_f = measured bulk specific gravity of sample after compaction
h_f = height of sample at last compacted gyration
h_x = height of sample at x^{th} gyration

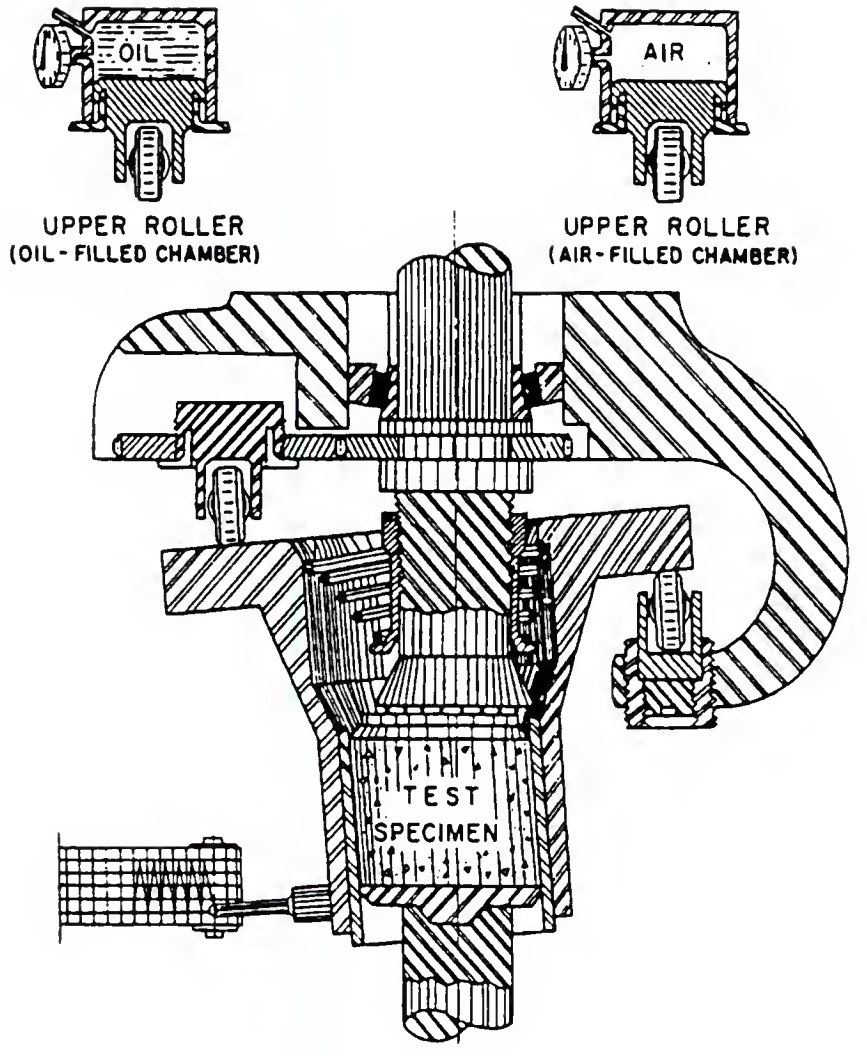

Figure 6. Schematic of the Gyratory Testing Machine

An example of the compaction results is shown in Figure 7. This graph of %Gmm versus gyrations shows how the number of gyrations to achieve the average, initial, in-place field density was selected.

5.2.2 GTM Densification/Shear Test

The GTM densification/shear test, which was also initially developed by Ruth and Schuab [41], is intended to simulate traffic densification. This procedure was recommended as a part of the AAMAS study [23] for the evaluation of rutting potential for dense-graded mixtures. The test was performed at 60°C to be representative of the pavement during the hottest part of the year. The densification/shear test was performed on previously compacted samples that were left in the molds and using the same GTM settings as used in compaction: 100 psi ram pressure, 3 degree initial angle of gyration, and 9 psi initial air roller pressure. Generally, the samples were densified to 300 gyrations or until a significant loss of shear strength occurred. Equation 2 was used to calculate the gyratory shear strength of the mixture during the test.

$$\tau G_x = 7.216 \frac{ARP_x}{h_x} \quad (2)$$

where:

τG_x = gyratory shear strength at gyration x, psi
ARP_x= Air Roller Pressure at gyration x, psi
h_x = height of sample at gyration x, inches

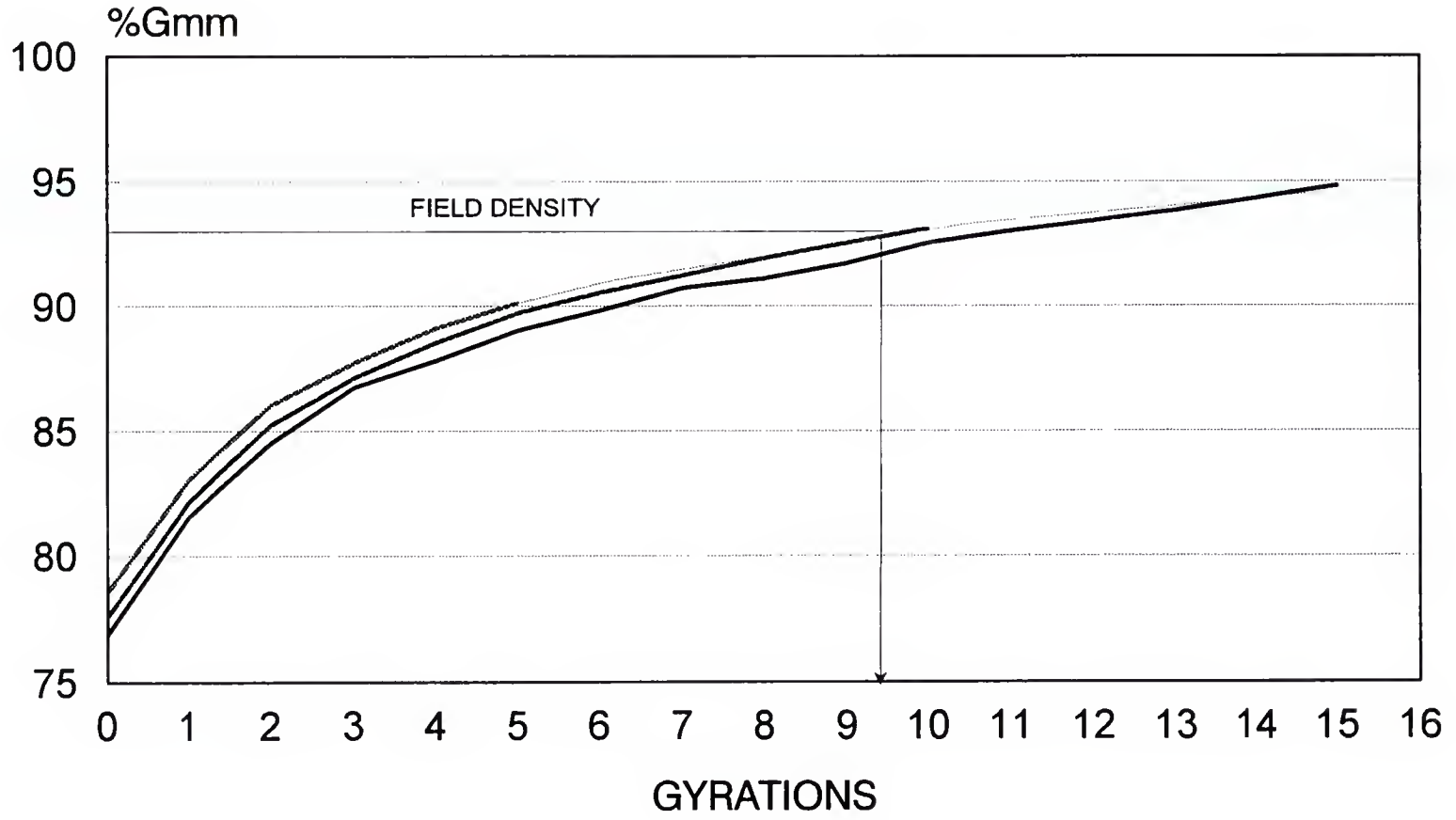

Figure 7. Example Plot of GTM Compaction Tests for Determining Number of Gyrations to Achieve Field Density

The change in the percent of air voids (i.e. Percent Densification) during the test was calculated using equation 3.

$$Z_x = \%Gmm_x - \%Gmm_i = \%AV_i - \%AV_x \quad (3)$$

where:

Z_x = percent densification at gyration x
$\%Gmm_i$ = percent of maximum specific gravity at start of the densification test
$\%Gmm_x$ = percent of maximum specific gravity at gyration x
$\%AV_i$ = percent air voids at start of the densification test
$\%AV_x$ = percent air voids at gyration x.

Typical results from the GTM densification/shear test are shown in Figure 8.

5.2.3 Georgia Loaded Wheel Tester

The Georgia Loaded Wheel Tester (GLWT), shown in Figure 9, was developed by Lai [33,42] for the Georgia Department of Transportation to evaluate the rutting potential of asphalt mixtures. Several studies have shown that results of the GLWT can accurately discriminate the rutting potential of dense-graded mixtures relative to their actual known field performance [33,34]. The Georgia DOT has reported very good results from GLWT tests on their SMA mixtures [30,31].

The GLWT test specimens in this study were 1.5"x3"x15" asphalt concrete beams. The prepared materials were heated to 300°F, mixed, then placed in molds and returned to the oven prior to compaction. Compaction was accomplished with a hydraulic compression machine by applying loads through a steel plate covering the top of the beam. The load was increased up to 60,000 lbs., then released and repeated four times. On the

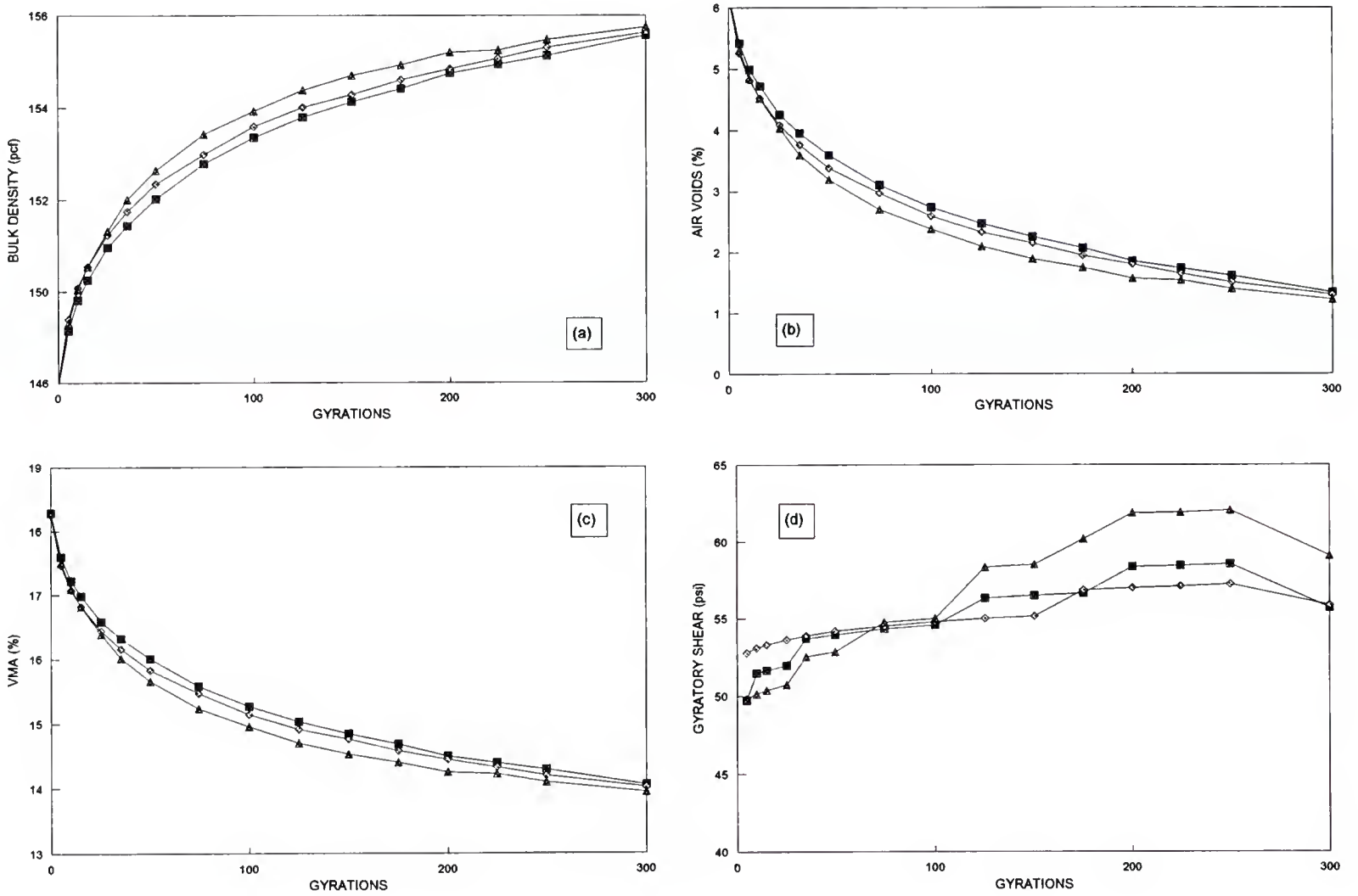

Figure 8. Example of Densification/Shear Test Results: (a) Density, (b) Air Voids, (c) VMA, and (d) GTM Shear Strength.

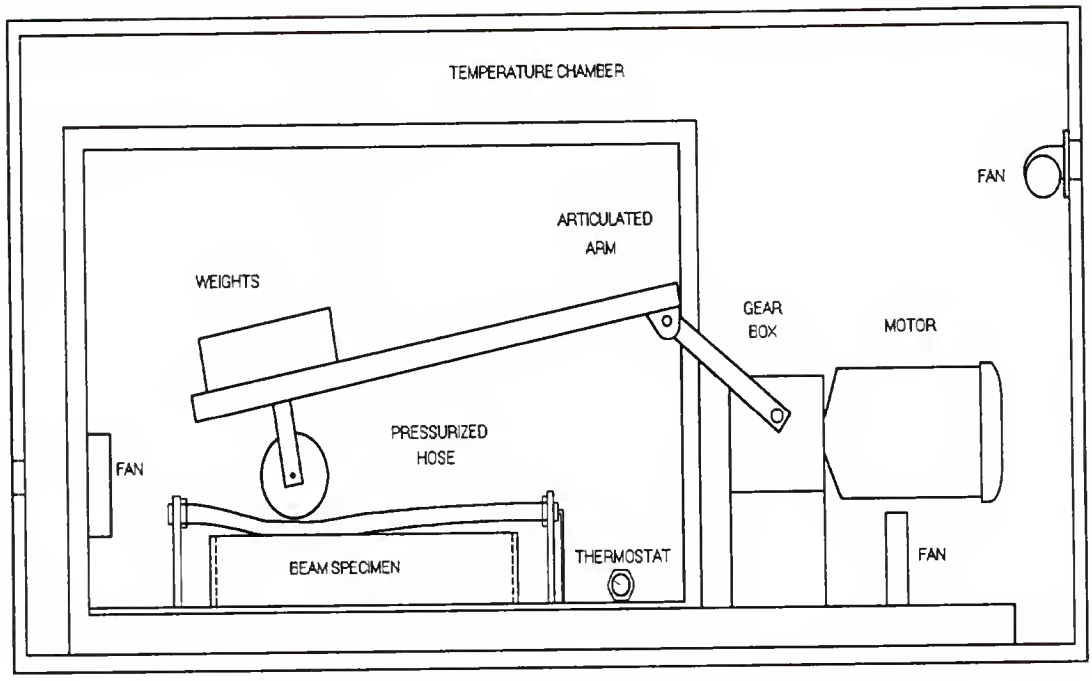

Figure 9. Illustration of the Georgia Loaded Wheel Tester

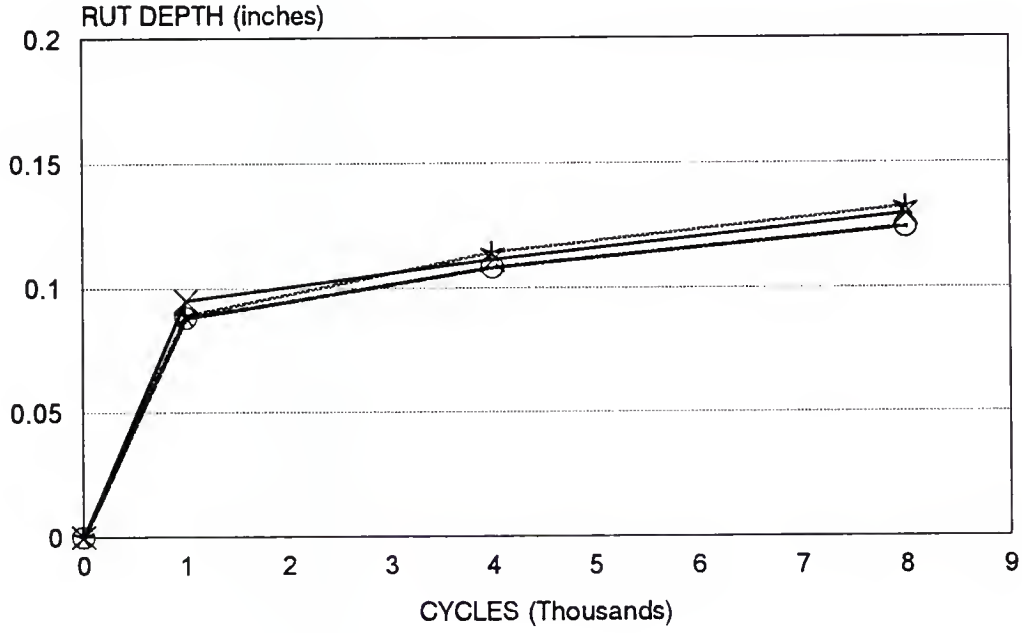

Figure 10. Example of Results from the Georgia Loaded Wheel Test

fifth application, the load was held at 60,000 lbs. for five minutes. The compacted beams were removed from the molds the next day and allowed to cure at room temperature for one day. During the curing period, bulk density and air void content for each beam was determined. Prior to testing, each beam was placed in the preheating chamber at 105°F for 24 hours.

The beams were rigidly confined on the sides and ends with angle brackets during the test. A stiff hose pressurized to 100 psi was mounted along the top of the beam acts as a tire to transfer the load from the wheel of the moving chassis to the beam. The chassis, loaded with 122 pounds, was driven by the motor / gear-box assembly through the articulated arms. One loading cycle consisted of a forward and return pass of the loaded chassis. The entire GLWT assembly was housed in a heated and insulated temperature chamber which maintained the test temperature at 105 ±3°F. Small fans were placed within the chamber to circulate the air. Rut depth measurements were made at three locations near the center of the beams with a dial gauge and reference template at 0, 1000, 4000, and 8000 cycles.

Figure 10 shows how typical results for the Georgia Loaded Wheel Tester are graphed to illustrate rut depths versus cycles. A criteria for maximum acceptable rut depth for dense-graded mixtures was tentatively set at 0.15 inches at 8000 cycles by West et al. [34].

5.2.4 Triaxial Repeated-Load Test

Triaxial repeated-load tests have been used by a number of researchers to evaluate the permanent deformation (rutting) potential of asphalt mixtures. Gabrielson [35] evaluated several rutting tests using dense-graded mixtures with known performance and concluded that the triaxial repeated-load test best models in-situ permanent deformation. A good correlation was shown to exist between laboratory strain and rutting rate (rut depth/square root of ESAL's in millions). The same test configuration was used by Brown and Manglorkar [26] to evaluate SMA mixtures with variations in mixture components.

The triaxial repeated-load test consisted of applying a constant confining pressure to a standard cylindrical specimen and a repeated axial stress for 3600 cycles to simulate traffic loading. The test conditions were set to realistically simulate the critical field conditions which lead to rutting as close as possible. The test temperature was 60°C to simulate high pavement temperatures. The axial deviator stress was applied using a 0.1 second haversine load period followed by a 0.9 second rest period to simulate 60 mph traffic. Although a single confining pressure cannot replicate the horizontal stress distribution existing in a pavement, Gabrielson found that 20 psi confining pressure gave very low variation in test results. The deviator stress level was set at 100 psi to give a total axial stress of 120 psi which is typical of the high contact pressures existing beneath the pavement and tires of heavy trucks. Figure 11 is an illustration of the triaxial repeated-load test assembly.

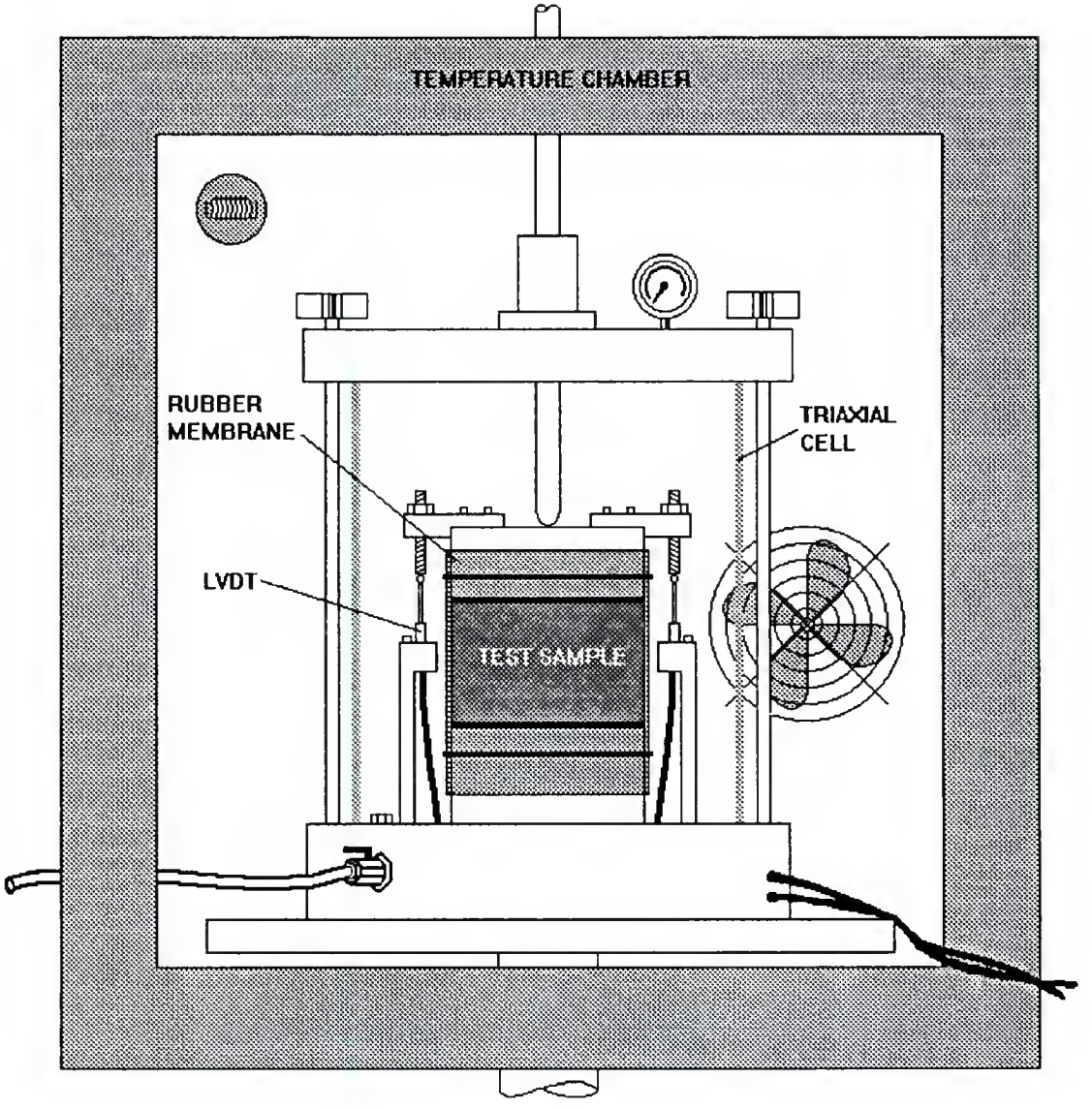

Figure 11. Illustration of the Triaxial Load Test Apparatus

Specimens for the triaxial repeated-load test were standard 4 inch diameter by 2.5 inch thick specimens compacted in the Gyratory Testing Machine. Specimen ends were smoothed with sandpaper. Prior to testing, specimens were preheated to 60°C for 4 to 6 hours. Thin Teflon sheets were also placed between the specimen and platens to eliminate shear stresses on the specimen faces. A rubber membrane was placed around the specimen and platens and held by o-rings at the top and bottom platen. Once the rubber membrane was in place, the triaxial cell was placed over the specimen and the confining pressure was applied. The entire triaxial assembly was then placed in the test environmental chamber and allowed to stabilize at 60°C for 20 to 30 minutes. Following the temperature equilibration time, 100 cycles of conditioning load was applied. The conditioning load was set to produce 20 psi of axial deviator stress.

The cyclic deviator stress was applied with a MTS servo-hydraulic test station. Axial deformations were measured by two independent LVDT's mounted inside the triaxial chamber on opposite sides of the specimen. Test control and data acquisition was accomplished through a MTS Model 458.20 microconsole using modified MTS software on a 386 PC. An example plot of results from the triaxial repeated-load test is shown in Figure 12. The slope of the permanent strain versus cycles (i.e. permanent strain rate) was used to characterize rutting potential of the study mixtures. Permanent strain rates were calculated using Equation 4.

$$\epsilon'_P = \frac{\frac{h_x - h_i}{h_i}}{c_x} \quad (4)$$

where:

ϵ'_P = Permanent Strain Rate, in/in/cycle
h_x = height of sample at cycle x, inches
h_i = height of sample at end of conditioning, inches
c_x = cycle number

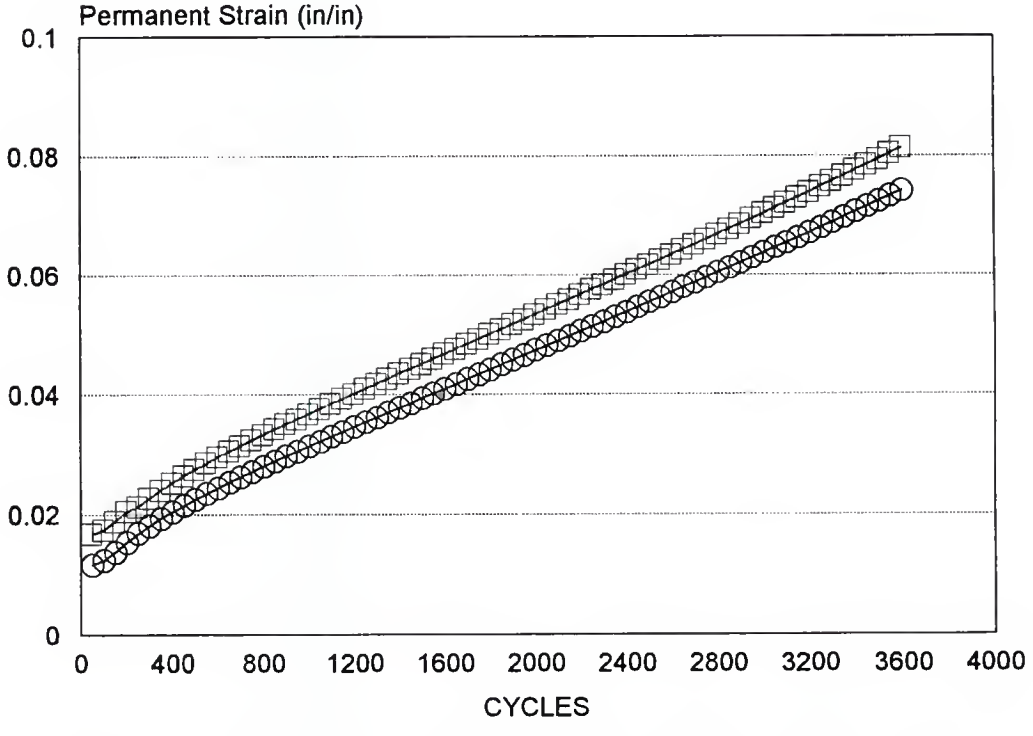

Figure 12. Example Plot of Results from Triaxial Repeated Load Tests

5.2.5 Indirect Tensile Strength Test

Tensile properties of the SMA mixtures were determined using the indirect tensile (diametral) test for evaluating cracking potential and moisture damage resistance. The indirect tensile strength tests were performed at 77°F (25°C) following the loading guidelines of ASTM D 4123 with a ram rate of 2 inches/min (50 mm/min). Tests were performed on GTM compacted samples using an MTS servo-hydraulic testing machine with a model 458.20 controller. Horizontal deformations were measured using an MTS model 632.94E-20 extensometer fixture. The test set-up for the indirect tensile test is illustrated in Figure 13. Test control, data acquisition and calculations were performed by software originally developed by MTS. The program for indirect tensile strength was modified to capture horizontal strain data and to calculate fracture energy. Tensile strengths and strains at failure were calculated using Equations 5 and 6, respectively. Fracture energy for each test was determined as the area beneath the stress-strain curve to the point of failure.

$$\sigma_T = \frac{2\ P_{ult}}{\pi\ d\ t} \tag{5}$$

where:

σ_T = tensile strength, psi
P_{ult} = ultimate applied load required to fail sample, lbs
d = diameter of sample, inches
t = thickness of sample, inches

$$\epsilon_f = 100(0.52\delta h) \tag{6}$$

where:

ϵ_f = strain at failure, %

δh = horizontal deformation corresponding to P_{ult}, inches

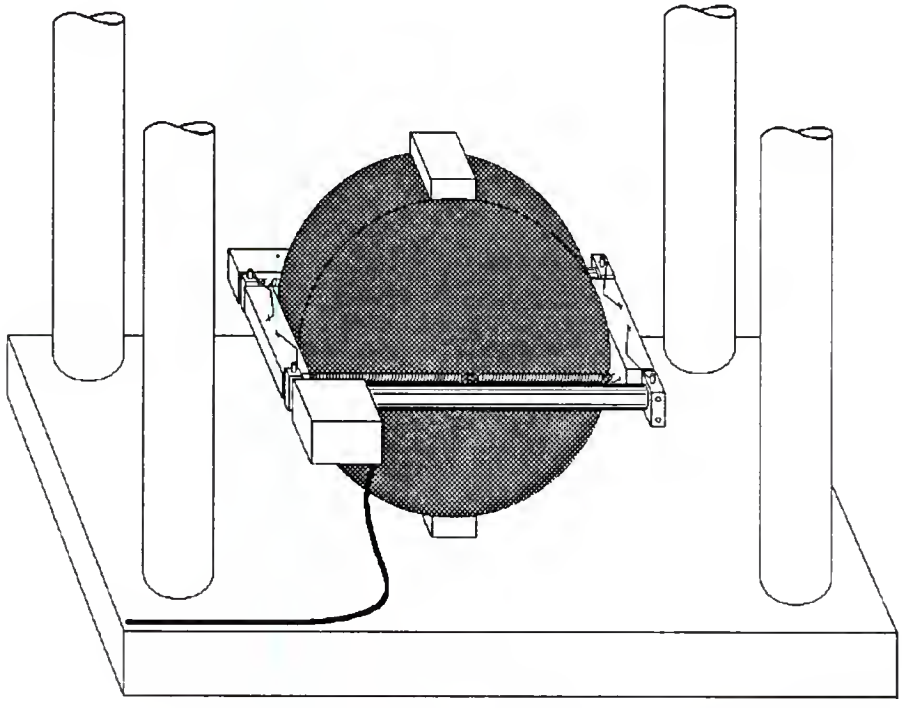

Figure 13. Illustration of Diametral Testing Configuration

5.2.6 Resilient Modulus

Total resilient moduli of the GTM compacted mixtures were determined in accordance with ASTM D 4123. Moduli were determined at three temperatures: 41°F, 77°F and 104°F (5°C, 25°C, and 40°C). Assumed Poisson's ratios were input for each temperature to avoid errors resulting from inaccurate vertical deformations caused by localized strains near the loading strips. For each sample and each condition, the resilient modulus was determined on two orthogonal axes. Total resilient moduli were calculated using Equation 7.

$$M_{R_T} = \frac{P\ (\nu + 0.27)}{t\ \delta h_T} \tag{7}$$

where:

M_{RT} = total resilient modulus, psi
P = repeated load, lbs
ν = Poisson's ratio, assumed ν=0.2 at 5°C, ν=0.35 at 25°C, and ν=0.5 at 40°C
δh_T = total recoverable horizontal deformation, inches

5.2.7 Creep Compliance

Static diametral creep tests were performed using guidelines taken from several sources including the AAMAS procedure [23] and the provisional AASHTO standard TP9 [43] developed in the Strategic Highway Research Program. A program was developed to provide test control, data acquisition, and perform calculations for the creep compliance test. All tests were performed at 14°F (-10°C) by applying a static load to the specimen's vertical diameter through 0.5 inch loading strips as used in the indirect tensile and resilient modulus tests. The magnitude of the load was set to produce between 50 and 200 horizontal microstrains at 60 seconds. The load was maintained for 1000 seconds, then removed and recovery of the horizontal strain was recorded for an additional 1000 seconds. Creep compliance was calculated using Equation 8. The percent recovery of the horizontal strain was calculated using Equation 9.

$$D_t = \frac{0.0875\ \pi td\ \delta h_t}{P_t} \quad (8)$$

where:

D_t = Creep Compliance at time t, square inches per pound
δh_t = horizontal deformation at time t, inches

$$R = 100\ \frac{\delta h_{t\ -\ 2000}}{\delta h_{t\ -\ 1000}} \quad (9)$$

where:

R = percent recovery
$\delta h_{t=2000}$ = horizontal deformation at end of unload period
$\delta h_{t=1000}$ = horizontal deformation at end of load period

5.2.8 Moisture Conditioning

To evaluate the potential for moisture damage, a.k.a. stripping, of asphalt mixtures, wet/dry tensile strength tests or resilient modulus tests are commonly performed. Standardized procedures for the wet/dry indirect tensile strength tests include ASTM D 4867 [37] and AASHTO T 283 [36].

In this study, comparisons were made between wet (moisture conditioned) and dry (unconditioned) resilient moduli and indirect tensile strengths. Figure 5 showed how the testing plan was set up to utilize specimens which had been used in non-destructive tests for the moisture conditioning evaluation.

Moisture conditioning consisted of vacuum saturation in tap water until specimens reached 60 to 100 percent saturation. Generally, this required one to two minutes under a vacuum of 100 mbars. For specimens with lower air voids, the vacuum time was extended to meet the saturation requirement. Following vacuum saturation, the specimens were placed in a 60°C water bath for 24 ±0.5 hours. Testing at 25°C was initiated within 24 hours after removal from the water bath.

CHAPTER 6
EVALUATION OF MIXTURE TEST DATA

6.1 GTM Compaction

Compaction results of the eleven duplicated field mixtures are shown in Table 9. The number of gyrations to achieve the field density ($N_{initial}$) was estimated from the compaction curves generated from three samples typically compacted to 12, 15 and 18 gyrations. Estimated values of $N_{initial}$ ranged from 5 to 20, with an average of 12.1 and a standard deviation of 4.5. Excluding the data from WI2, which was apparently undercompacted in the field, does not significantly alter these statistics. The average initial in-place air void content for the field SMA mixtures was 6.9 percent. Excluding WI2 does drop the average to 6.5 percent.

The air void content and VMA data for each mixture, shown in Table 9, are the results of six samples compacted to $N_{initial}$. Several mixtures had very small variations in air void contents, for others the repeatability was poor. In most cases, the estimated value of $N_{initial}$ did yield sample air void contents that were reasonably close to the target field air void content for the six compacted samples. Using the data generated from the six samples from each mixture, the adjusted estimate of $N_{initial}$ was made, but these values were only slightly different.

Table 9. Compaction Results for the Duplicated Field Mixtures

Mix I.D.	Average Field Air Voids (%)	Estimated $N_{initial}$	Compacted Air Voids (%)	Compacted VMA (%)	Adjusted $N_{initial}$
GA1	5.0	12	4.3 4.3 4.1 4.2 3.7 4.0	16.5 16.5 16.4 16.5 16.0 16.3	10
GA2	7.0	5	7.0 5.2 6.8 6.6 6.3 6.3	18.2 16.7 18.1 17.9 17.7 17.6	4
GA3	6.3	16	6.5 6.3 5.7 6.0 5.8 6.5	19.6 19.3 18.8 19.1 18.9 19.5	15
GA4	5.7	15	6.2 5.7 6.0 5.9 6.3 6.1	18.5 18.0 18.2 18.2 18.6 18.4	16
WI1	6.8	20	6.8 7.5 7.2 6.7 7.5 7.9	17.4 18.0 17.7 17.3 18.0 18.4	22
WI2	10.5	5	10.1 9.9 10.2 9.9 9.8 9.2	20.6 20.4 20.7 20.4 20.4 19.8	4
WI3	7.6	12	6.9 4.7 6.4 5.5 5.7 7.0	18.5 16.6 18.1 17.3 17.4 18.6	9
WI4	6.5	11	6.5 4.7 6.9 6.0 6.4 5.4	18.1 16.5 18.4 17.7 18.0 17.2	11
MD1	5.9	12	5.9 6.5 6.5 5.8 7.1 6.1	20.9 21.5 21.5 20.9 22.0 21.1	13
TX1	7.0	10	7.3 6.8 7.0 8.3 6.9 6.3	20.3 19.9 20.1 21.3 20.0 19.5	10
VA1	7.3	15	6.2 6.4 4.9 5.6 5.9 4.6	19.8 20.2 18.7 19.3 19.5 18.4	9

One purpose of the compaction tests on the duplicated field mixtures was to develop a standard compactive effort to be used for the design of experimental mixtures. When the first few mixtures of this study had ben tested, a quick, rough analysis indicated that about 15 gyrations would generally provide the appropriate level of compaction. This was used as the standard compaction effort for the experimental SMA mixtures using Florida aggregates. Based on more complete data, it now appears that about 12 gyrations would be closer to the average $N_{initial}$ for the mixtures evaluated.

6.2 Design of Experimental Mixtures

Since the experimental mixtures had fixed gradations and components, the only variable in the mix design was selection of the design asphalt content. Samples for each experimental mixture were prepared with a range of asphalt contents and compacted in the GTM using 100 psi vertical pressure, 3 degree initial angle of gyration, 9 psi initial air roller pressure and 15 gyrations. Sets of samples were prepared with cellulose fibers and with ground tire rubber as stabilizing additives. The design asphalt content for each mixture was selected at 6.5 percent air voids. This was the average initial in-place air void content of the field mixtures included in this study. Tensile strengths and failure strains were also measured on each of the samples prepared for the asphalt content determination trials. Results are shown in Table 10. Conclusions drawn from this data are:

1. A half percent increase in asphalt content generally produces about a one percent decrease in air void content. This rule of thumb does not apply all of the time, but can be a very useful guideline for making mix adjustments.

2. For most mixtures, the highest tensile strengths occur at asphalt contents that yield between 6.0 and 7.0 percent air voids. Tensile strains at failure generally tend to increase with increasing asphalt contents and decreasing air void contents.

Table 10. Results of Experimental Mix Design Tests at 25°C

		CELLULOSE			GTR		
Mix I.D.	Asphalt Content (%)	Air Voids (%)	Tensile Strength (psi)	Failure Strain (%)	Air Voids (%)	Tensile Strength (psi)	Failure Strain (%)
FL1	5.0				7.7	83.7	0.75
	6.0	6.7	83.7	1.41	5.4	105.3	1.14
FL2	5.0	8.9	82.4	0.79	7.5	106.4	0.62
	5.5	7.9	85.3	0.85	6.3	108.2	0.64
	6.0	6.6	95.2	0.85	5.8	105.6	0.73
FL3	5.0	11.2	65.9	0.79	9.0	86.3	0.62
	5.5	9.1	71.0	0.96	8.0	89.1	0.79
	6.0	8.0	78.0	0.83	7.2	90.6	0.77
	6.5	7.7	73.8	0.92	5.6	105.2	0.75
FL4	5.5	8.1	73.5	0.92	7.0	89.4	0.75
	6.0	6.8	74.8	0.85	6.2	100.5	0.77
	6.5	5.2	87.9	0.89	4.8	105.5	0.71
	7.0	4.4	84.0	1.08	3.9	107.9	0.89
FL5	4.5	9.1	86.5	0.79	7.9	109.8	0.75
	5.0	8.0	97.0	0.92	5.8	151.1	0.71
	5.5	7.2	105.3	0.79	5.8	126.9	0.71
	6.0	5.1	113.1	0.81	4.2	130.0	0.96
FL6	4.0	10.8	62.1	0.79	7.0	110.2	0.71
	4.5	9.5	62.8	0.73	5.8	107.6	0.73
	5.0	7.3	72.5	0.87	4.9	113.2	0.85
	5.5	6.7	71.8	0.98	4.2	110.7	0.87

3. Cellulose fibers tend to bulk mixtures more than ground tire rubber (and most other additives as well) and therefore, will allow for more asphalt in mixtures at equal air void contents. Increased asphalt contents will likely result in mixtures that are more resistant to thermal and fatigue cracking.
4. At equal asphalt contents, mixtures with ground tire rubber have higher tensile strengths but lower failure strains than cellulose mixtures. Also, at approximately equal air void contents (equal densities), mixtures containing ground tire rubber have higher tensile strengths and lower failure strains. These effects are related to conclusion number 2.

After selecting the design binder content, additional samples were compacted for the other tests. Average weight-volume data from these compacted samples are shown in Table 11.

Table 11. Weight-Volume Data for Experimental Mixtures Compacted 15 Gyrations

Stabilizer	Cellulose			Ground Tire Rubber		
Mix I.D.	A.C. Content (%)	Air Voids (%)	VMA (%)	A.C. Content (%)	Air Voids (%)	VMA (%)
FL1	7.0	6.4	17.4	6.0	7.1	16.0
FL2	5.9	6.8	16.1	5.3	7.3	15.4
FL3	6.7	6.2	17.9	6.2	6.7	17.2
FL4	6.1	6.2	17.0	5.8	6.4	16.6
FL5	5.5	6.3	18.7	5.0	6.4	17.4
FL6	5.5	7.3	18.9	4.7	7.1	17.1

6.3 GTM Densification/Shear Tests

Results of the GTM densification/shear tests for all mixtures are summarized in Table 12. The shear strength trends (in the first row) indicate the general pattern of the gyratory shear strength versus gyrations plots between 200 and 300 gyrations. Trends are reported as rising (increasing shear strength), stable (little or no change in shear strength) or declining (shear strength loss and tending toward failure). Trends for most of the SMA mixtures are either stable or rising which indicates that the mixtures would provide good shear resistance under traffic. Three mixtures (GA2, GA4, and WI1) had declining shear strengths. Mixtures GA2 and WI1 were retested under the same conditions but with a different operator. Results of the retests are shown in parentheses. Insufficient material was available to retest GA4. The retest results for GA2 and WI1 show that these mixtures performed much better than indicated by the original test results. All data for these mixtures were carefully reviewed, but no reason was evident for the difference between the original and retest results. Based on the available field data it is expected that all of the duplicated field mixtures would have stable shear strengths.

The value of the shear strength at 200 gyrations is shown in the second row. Shear strengths for the SMA mixtures vary considerably, ranging from 50.4 psi for one WI3 sample to 67.0 psi for one of the FL1 samples. There is also some variation within replicate samples of the same mixture. An analysis of variance was performed to determine if significant differences in shear strength existed between the mixtures.

The statistical procedure used in this analysis was a simple one factor fixed-effect model. The statistical tool of residual analysis was applied for model adequacy checking.

Table 12. Results of the GTM Densification/Shear Tests

Mix I.D.	GA1	GA2	GA3	GA4	WI1	WI2	WI3	WI4	MD1	TX1	FL1	FL2	FL3	FL4	FL5	FL6
Shear Strength Trend	rising	decline (stable)	stable	decline	decline (stable)	stable	rising	stable	stable	rising	rising	rising	rising	rising	rising	stable
GTM Shear Strength at 200 Gyrations (psi)	64.7 63.5 62.0	52.0 50.3 51.6 (62.8) (64.3)	53.6 58.4 58.1	50.7 52.4 52.5	50.9 49.8 51.3 (59.2)	53.5 57.5 55.9	50.4 56.3 55.3 57.9 54.7	54.9 55.7 53.8	52.7 58.4 51.8	51.9 52.3 50.9	65.6 67.0	60.3 62.5 66.8	55.8 57.1 55.3	53.6 52.2 58.7	60.2 62.6 64.0	59.5 58.1 62.5
Percent Densification at 200 Gyrations (%)	1.9 0.8 1.8	3.8 4.7 4.0 (2.8) (2.2)	2.6 2.0 3.4	1.7 3.4 3.0	3.4 2.9 2.9 (3.9)	5.5 1.4 7.2	3.0 4.6 3.1 3.4 5.0	3.8 2.0 1.4	4.5 4.2 5.0	4.8 3.6 5.5	3.3 3.6	4.8 5.1 3.8	3.9 5.3 5.3	4.8 5.8 5.3	3.7 3.8 3.9	2.3 1.9 2.3
Initial Air Void Content (%)	4.3 2.9 4.0	6.3 7.1 6.3 (6.2) (5.7)	5.6 4.5 6.1	4.5 6.2 5.8	7.6 6.6 6.8 (8.4)	9.0 3.8 9.8	4.5 6.4 4.7 5.5 7.0	6.6 2.8 2.9	5.9 5.8 7.3	7.0 5.5 7.5	7.2 6.8	7.0 8.2 6.5	5.2 7.3 7.2	6.1 6.7 6.1	5.8 6.5 6.7	6.3 5.5 6.2
Initial VMA (%)	16.5 15.4 16.3	17.6 18.3 17.6 (17.5) (17.1)	18.8 17.8 19.2	17.0 18.4 18.1	18.1 17.2 17.4 (18.8)	19.7 15.0 20.3	16.4 18.0 16.6 17.3 18.6	18.2 14.8 15.0	20.9 20.9 22.1	20.1 18.8 20.5	16.2 15.8	15.1 16.2 14.6	15.8 17.7 17.6	16.4 17.0 16.4	16.8 17.5 17.6	16.2 15.5 16.1
Weight Loss (g)	16.9	13.4	1.1	11.8	4.6	14.7	7.7	2.5	8.4	1.0	4.0	6.6	2.7	1.6	4.6	1.5

Note: Results in parentheses are retests.

Since unbalanced data exist in some cases, SAS procedure PROC GLM was selected and used throughout this study. A Duncan's multiple range test with a significance level (α) of 0.05 was applied to compare the means for the different mixtures.

Results of this statistical analysis are illustrated in Figure 14. This bar graph shows the average gyratory shear strength for each mixture, with the mixtures ordered from highest to lowest shear strength. Letters on the bars indicate mixtures which have mean shear strengths that are not significantly different. For example, the shear strength, τG_{200}, for FL6 is not significantly different than that of GA1 (shown with letter "A") and also not significantly different than FL3 (shown with letter "B"). However, FL6 is significantly different than FL1 and all other mixtures with lower shear strengths.

Based on criteria established by Ruth et al. [32] using dense-graded mixtures, the shear strength at 200 gyrations should be above 54 psi to assure good rutting performance. Application of that criteria to these SMA mixtures indicates that most of the mixtures are very rut resistant. The exceptions are GA4, TX1, and FL4. The original results of GA2 and WI1 were also below 54 psi, but the retest results were well above the criteria. For the mixtures which failed the criteria, only GA4 displayed a declining shear strength, yet this trend was gradual and not indicative of a catastrophic failure. Mixtures TX1 and FL4 were actually still gaining strength when the test was terminated.

The other parameter evaluated from the GTM densification test is the percent densification. This parameter is simply the change in air voids of the sample at any point during densification. Since the compaction procedure targets the initial in-place density, it is also necessary to limit the amount of consolidation (densification) that may occur due to

General Linear Models Procedure

Dependent Variable: Gyratory shear strength at 200 gyrations

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	15	968.53308	64.5688725	2.231	12.97	0.0001

$\alpha = 0.05$
R-Square = 0.866
C.V. = 3.947

Duncan Grouping

Means with the same letter are not significantly different

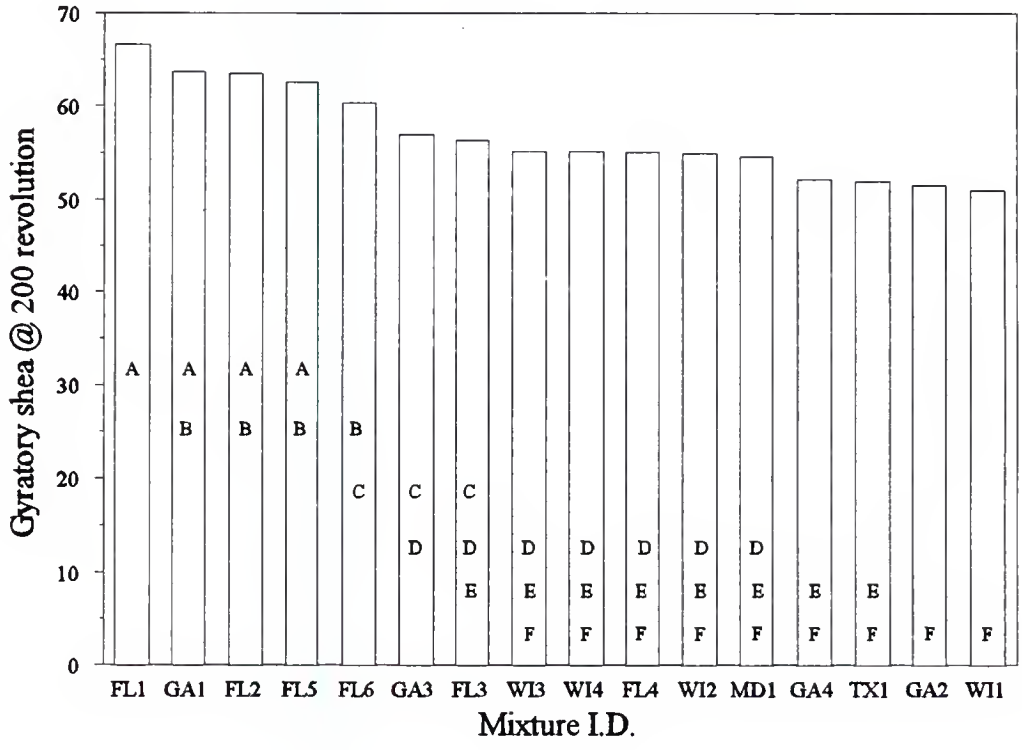

Figure 14. Comparison of GTM Shear Strengths

traffic. The general criteria used for dense-graded mixtures has been: ≤ 2.5% is good, ≤ 3.5% is acceptable, ≥ 4.0% is undesirable.

Results for many of the SMA mixtures (Table12, Row 4) indicate a potential for excessive densification. This data was analyzed with the same statistical procedures used to evaluate shear strengths. The results shown in Figure 15 show a more visually dramatic spread in the percent densification results. Yet due to the variation among replicates, mixtures having as much as 1.0 percent difference in means are not significantly different.

Initial air void contents and VMA's of the test samples are shown in the fifth and sixth rows, respectively. These parameters were believed to possibly have some affect on shear strength and percent densification results. Several plots were made to assist in identifying relationships between results and with other mix parameters. These results are shown in Figures 16 through 20. It can be seen that the only apparent correlation is between percent densification and initial air voids. This intuitive relationship indicates that mixture densification (consolidation rutting) will be lower when the as-compacted air void content is low. However, the gyratory shear strength of the SMA mixtures is not affected by initial air void content or percent densification. This supports findings by others [7,26] that the deformation resistance of SMA mixtures is not sensitive to low air void contents. This departure from the conventional wisdom used with dense-graded asphalt mixtures indicates that the shear strength of SMA mixtures is primarily dependent on the aggregate gradation, aggregate angularity and surface texture and binder content.

General Linear Models Procedure

Dependent Variable: Percent densification

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	15	62.185188	4.14567923	0.679	9.00	0.0001

$\alpha = 0.05$
R-Square = 0.818
C.V. = 17.897

Duncan Grouping

Means with the same letter are not significantly different

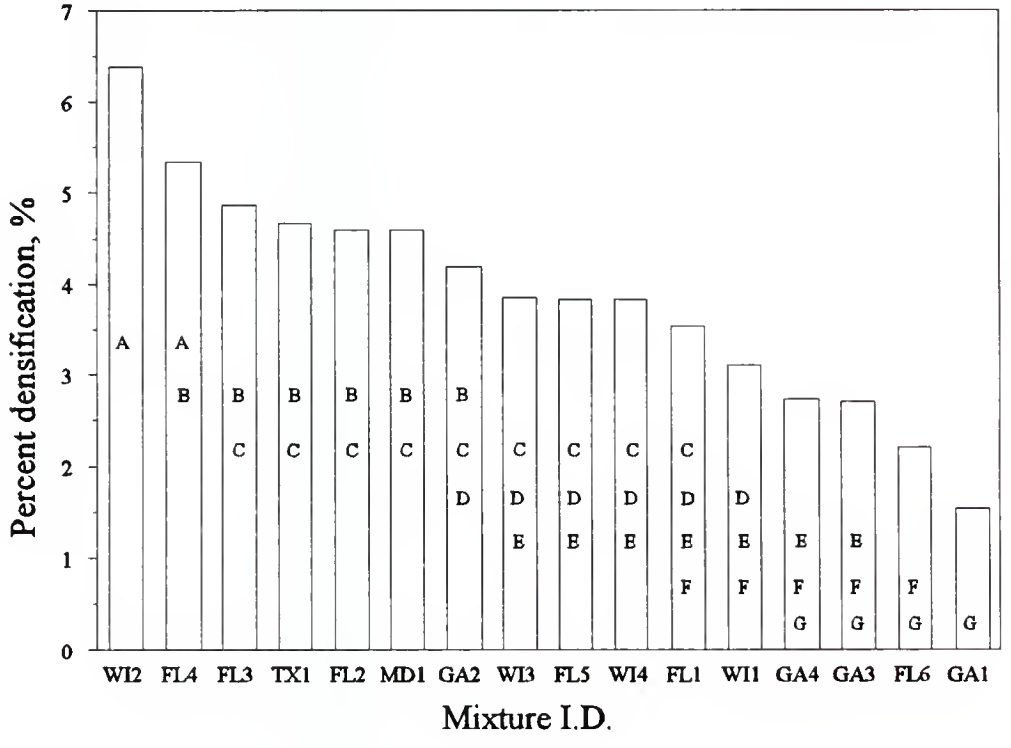

Figure 15. Comparison of GTM Percent Densification Results

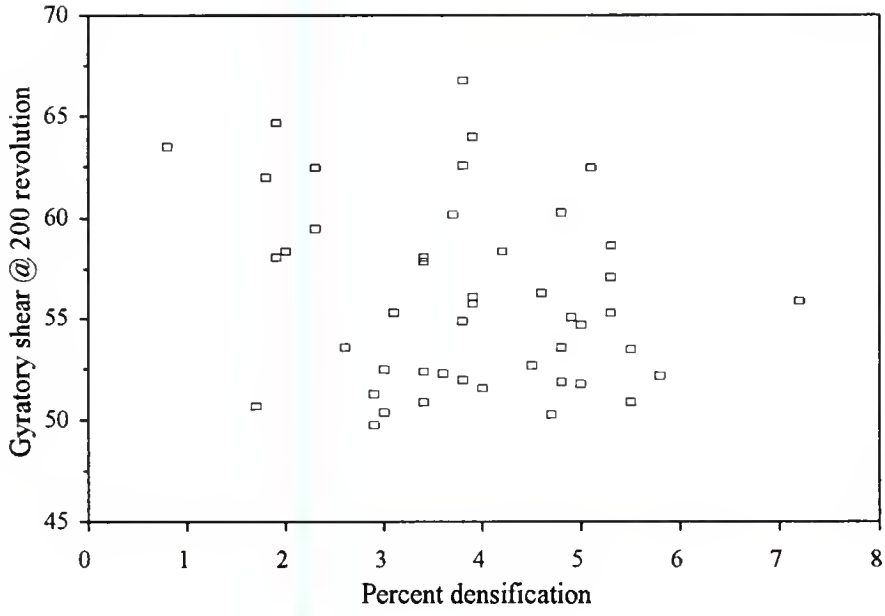

Figure 16. Gyratory Shear Strength versus Percent Densification Results at 200 Gyrations

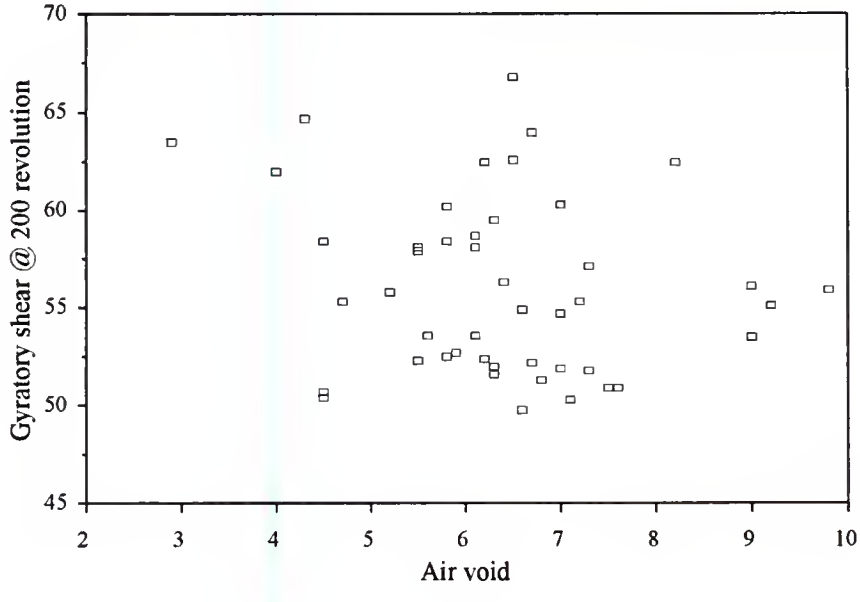

Figure 17. Gyratory Shear Strength at 200 Gyrations versus Initial Air Voids

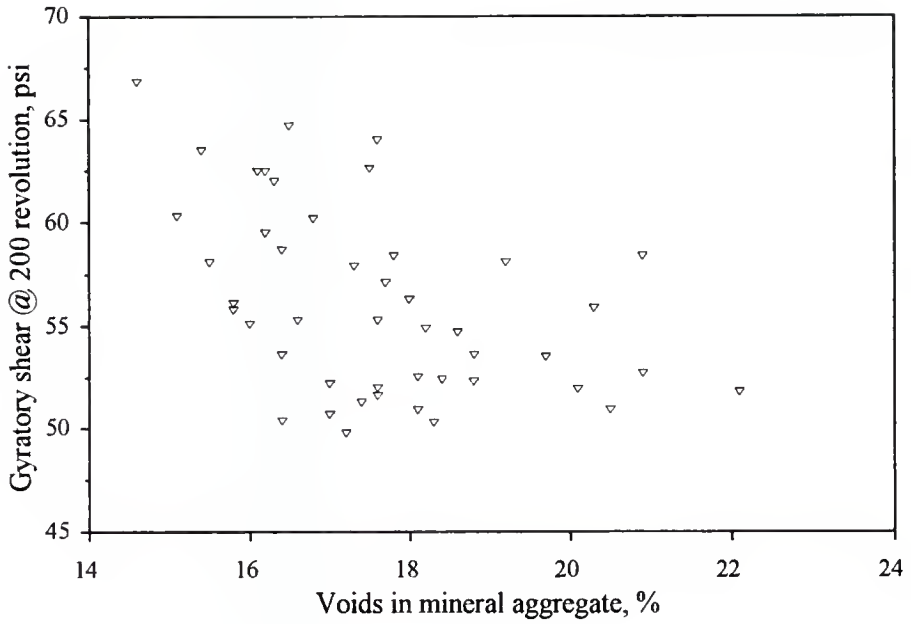

Figure 18. Gyratory Shear Strength at 200 Gyrations versus Initial VMA

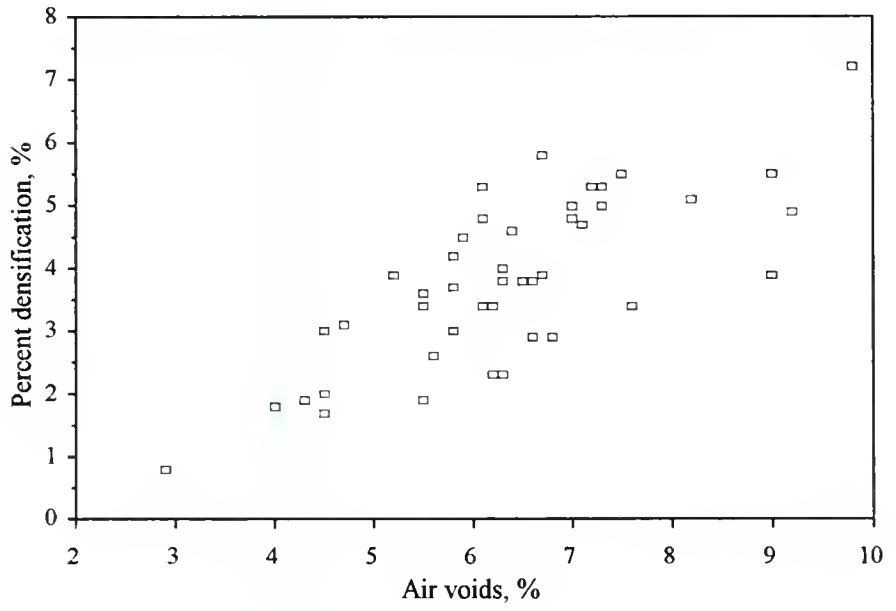

Figure 19. Percent Densification at 200 Gyrations versus Initial Air Voids

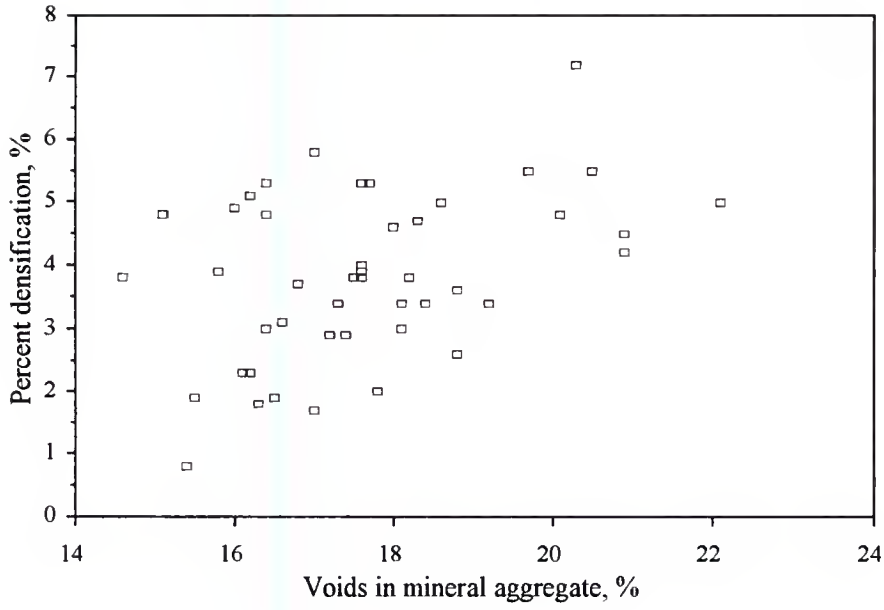

Figure 20. Percent Densification versus Initial VMA

The bottom row of Table 12, average weight loss, was included in the results as a potential indicator of flushing due to excessive asphalt content. During the densification/shear test, some samples would consolidate to a degree at which some mastic would flush out of the sample and squeeze out of the mold during the test. Flushing of the mastic often occurred well before the calculated sample air voids were below 2 percent. The amount of extruded binder was determined indirectly from the difference in average weights of samples extruded after compaction and the average weights of the densified samples. From the data it is apparent that flushing of the mastic does not correspond to low or declining shear strengths. For example, mixtures GA1 and WI2 had high weight

losses, but their shear strengths were high and very stable. As mentioned earlier, some flushing has occurred on several field SMA projects, yet these SMA mixtures have also remained very stable.

6.4 Georgia Loaded Wheel Tests

Results of the Georgia Loaded Wheel Tests (GLWT) are shown in Table 13. Due to shortages of some materials, triplicate samples were not possible for all mixtures.

Nearly all of the SMA mixtures performed very well in the GLWT. Visual inspections of the samples after the test indicated that the low magnitude ruts were due primarily to wearing away of the mastic, reorientation or seating of surface aggregate particles and minor consolidation. No lateral displacement was evident for any mixture except for TX1, which was very minor. Little rutting was apparent at the ends of the beams, which are often greatly distorted in DGAC samples. All of the mixtures except for TX1 easily met the maximum rut depth criteria of 0.15 inches.

Table 13. Results of the Georgia Loaded Wheel Tests at 8000 Cycles

Mix I.D.	GA1	GA2	GA3	WI2	WI3	WI4	MD1	TX1	VA1	FL1	FL2	FL3	FL4	FL5	FL6
Initial Air Voids (%)	3.9 4.0 4.0	7.4 7.3 7.4	6.9 7.4 6.0	6.0 6.5	5.1 3.8	7.2 5.5	5.3 4.7 4.3	5.1 5.4 5.2	6.1	8.9 8.5 8.9	6.0 6.4 5.0	5.7 4.7 4.4	5.8 5.0 5.6	5.6 6.1 6.1	7.3 7.4 6.0
Rut Depth (in.)	.079 .038 .044	.077 .061 .076	.102 .098 .105	.071 .100	.095 .094	.111 .143	.124 .115 .107	.150 .150 .175	.104	.073 .104 .085	.092 .079 .084	.143 .142 .106	.108 .097 .075	.110 .143 .137	.124 .130 .114

The air void data shown in Table 13 indicates that a reasonable level of compaction was achieved with the crude static compaction method. Nearly all sample air void contents were within the range expected to exist in the field after construction.

As can be seen in Figure 21, some mixtures were clearly more rut resistant than others. Statistical analysis of the rut depth data revealed a large number of statistical groupings for the fifteen mixtures. In general, the Florida experimental SMA mixtures compare well with the duplicated field mixtures. FL3 and FL5 were among the worst mixtures in terms of GLWT mean rut depths, yet they were statistically the same as GA3 which is known to be a very rut resistant mixture. The other FL mixtures can also be grouped with this baseline mixture. However, as indicated by the coefficient of variation, repeatability of this test is poor.

A plot of air void contents versus rut depths, shown in Figure 22, reveals no apparent correlation. This provides additional support to the conclusion that rutting resistance of SMA mixtures is not affected by air void contents.

6.5 Triaxial Repeated Load Tests

Results of the Triaxial Repeated Load Tests are shown in Table 14. According to this data, most of the mixtures appear to have very good deformation resistance. Criteria developed by Gabrielson [35] based on the field performance of 16 dense-graded mixtures was a maximum strain of 0.13 in/in for a test of 3600 cycles, or 3.61 E-5 strain/cycle. Twelve of the seventeen mixtures had results well this criteria. Mixtures WI4, MD1, and FL6 had values both above and below the criteria. Although the average values were

General Linear Models Procedure

Dependent Variable: Rut depth

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	14	0.02939337	0.00209953	0.015	9.65	0.0001

$\alpha = 0.05$
R-Square = 0.844
C.V. = 14.16

Duncan Grouping

Means with the same letter are not significantly different

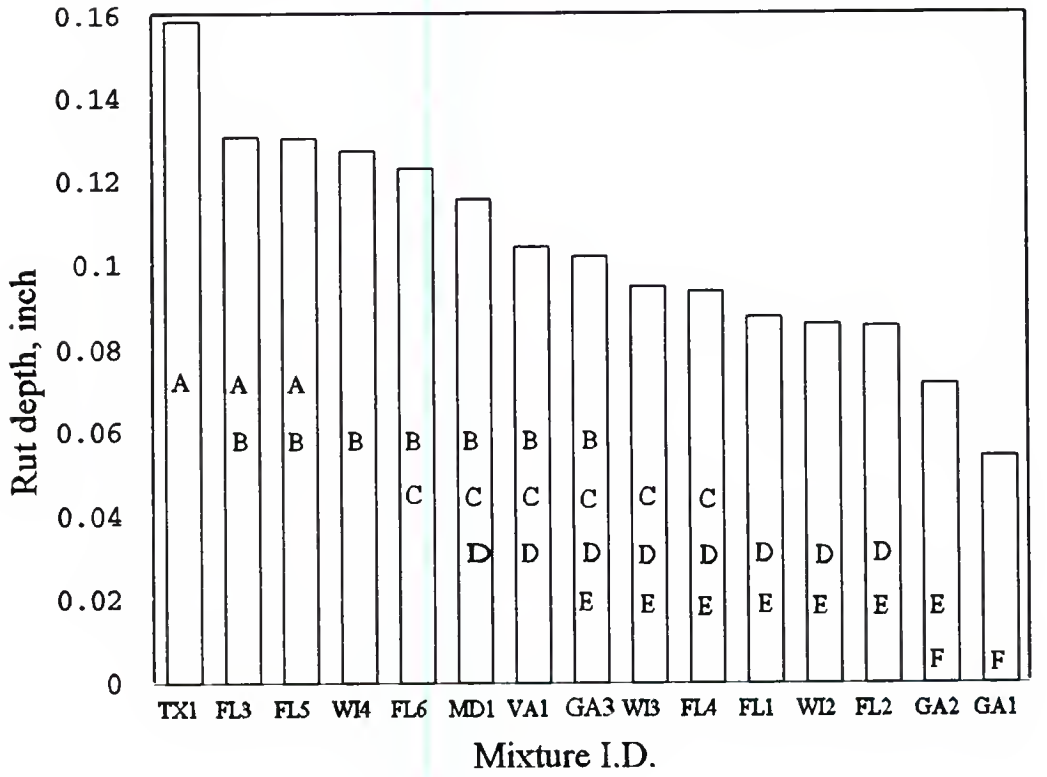

Figure 21. Comparison of GLWT Rut Depths

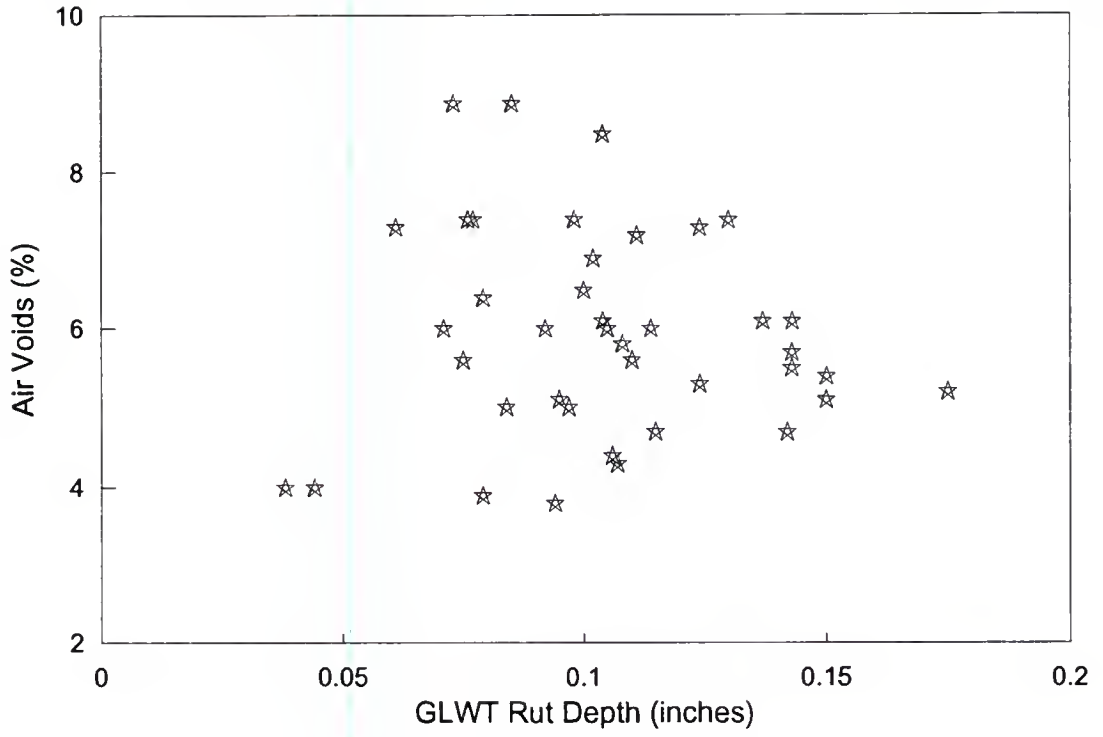

Figure 22. Plot of GLWT Rut Depths Versus Air Voids

Table 14. Results of the Triaxial Repeated Load Tests

Mix I.D.	GA1	GA2	GA3	GA4	WI1	WI2	WI3	WI4	MD1	TX1	VA1	FL1	FL2	FL3	FL4	FL5	FL6
Initial Voids (%)	4.2 4.0	6.6 6.3	6.0 6.0	5.9 6.1	6.8 6.7	10.1 10.2	6.5 6.4	4.7 6.0	5.9 5.8	6.8 8.3	5.1 6.2	8.8 8.7	6.9 6.7	6.3 6.6	6.4 6.7	7.0 7.0	5.5 6.3
ϵ_p rate (E-5 / cycle)	1.25 1.27	1.31 1.29	1.31 1.30	2.50 2.51	2.14 2.65	1.82 1.94	1.65 2.12	3.69 2.58	2.93 3.70	6.85 6.47	2.50 3.49	1.52 1.63	2.24 1.63	1.86 1.77	1.93 1.49	4.22 3.76	2.31 3.95

below the criteria, these mixtures were considered as having marginal deformation resistance. Two mixtures, TX1 and FL5, were above the criteria and would be considered to have poor deformation resistance.

The statistical comparison of the TRL results for the study mixtures is shown in Figure 23. Mixture TX1 is obviously significantly different from the other mixtures. Otherwise, there are broad groupings of results. Variability of the test is high as indicated by the high coefficient of variation.

6.6 Correlation of Rutting Tests

Comparisons were made between the results from the three tests which were used to indicate rutting potential to infer the adequacy of the tests and the data. First, if one or more of the tests results agree that a particular mix is good or bad then the confidence that the results are reasonable is increased. Conversely, if the results of one test are clearly out of the trend, it may be an indication that the test results are in error. Also, if results from one of the tests fails to consistently correlate with the results of the others, then it may indicate that the test is not representing the conditions critical for rutting or that the test affected by other variables.

To aid in the comparisons, results were plotted and least-square linear regressions were performed. First, shown in Figure 24, is the plot of GTM shear strength (τG_{200}) versus GLWT rut depth at 8000 cycles. The expected trend of increasing rut depth for lower shear strength is apparent, however, as indicated by the R^2 value of 0.34 the correlation is weak. The regressions were run again without the data from the FL mixtures and a much improved coefficient of determination was given ($R^2 = 0.79$). Output for the regressions are summarized in Table 15. The plot of GTM shear strength versus TRL permanent strain rate, Figure 25, also shows the expected trend, but the regression has a low coefficient of determination ($R^2 = 0.18$) when all data was included. The

General Linear Models Procedure

Dependent Variable: Permanent strain rate

Source	DF	Type I SS	Root MSE	F Value	Pr > F
MIX	16	0.00000001	0.000004	19.71	0.0001

$\alpha = 0.05$
R-Square = 0.949
C.V. = 16.939

Duncan Grouping

Means with the same letter are not significantly different.

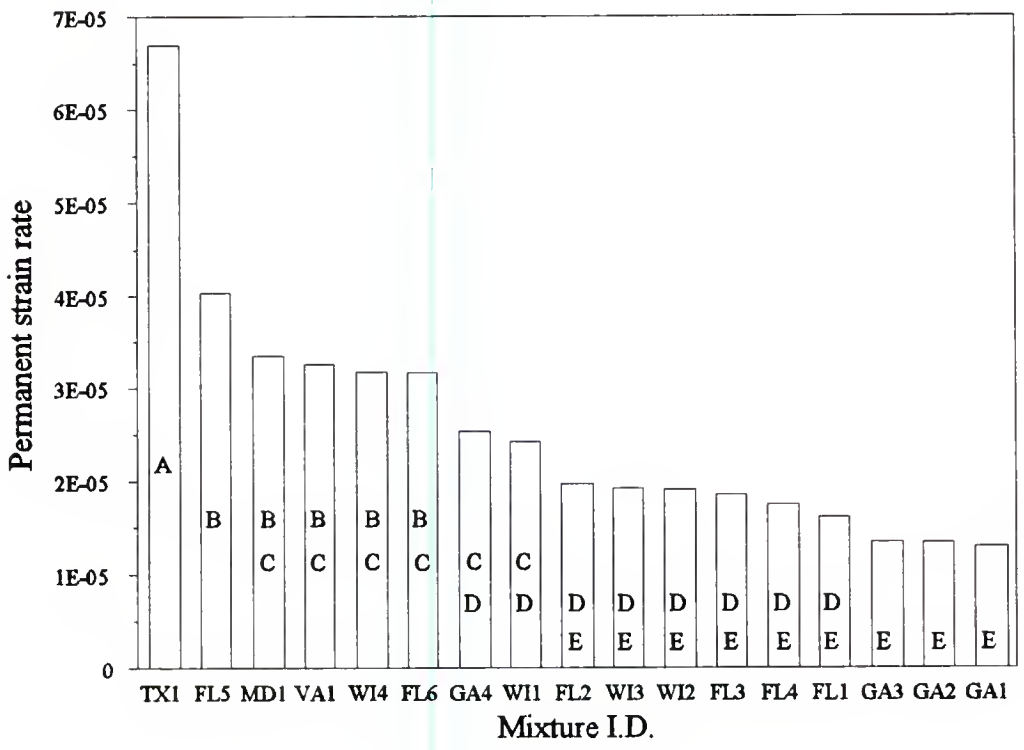

Figure 23. Comparison of Permanent Strain Rates

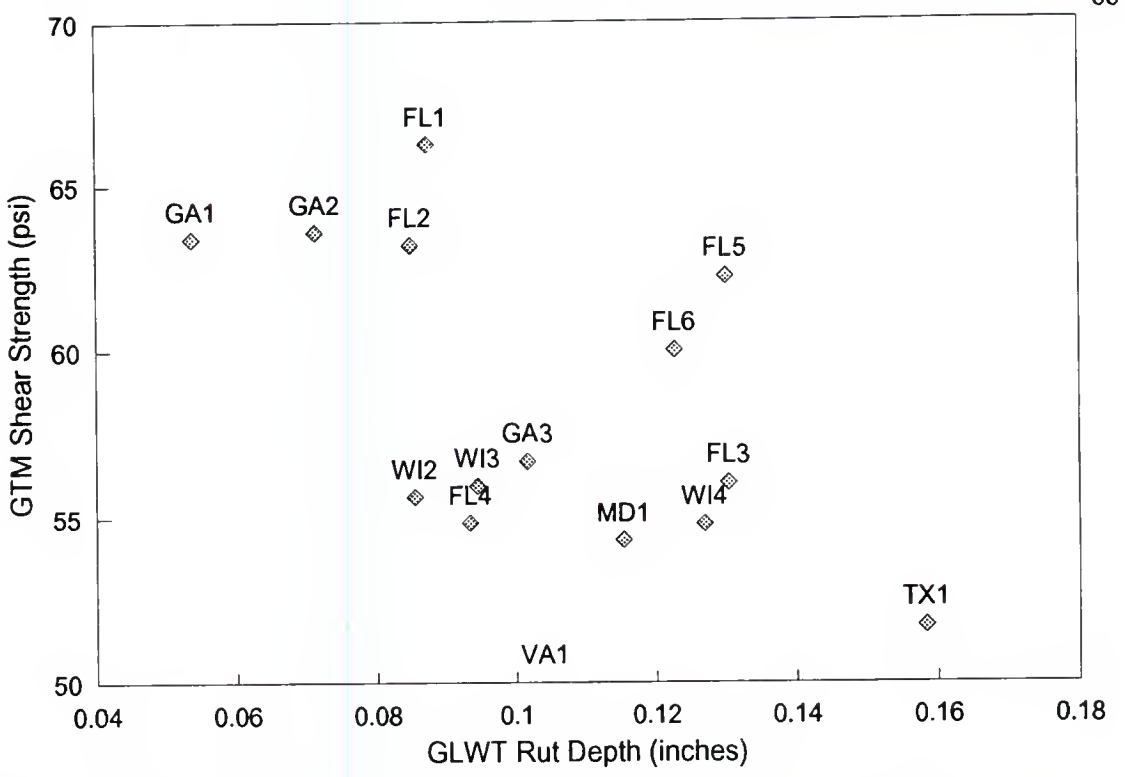

Figure 24. Plot of Gyratory Shear Strength at 200 Gyrations versus GLWT Rut Depth

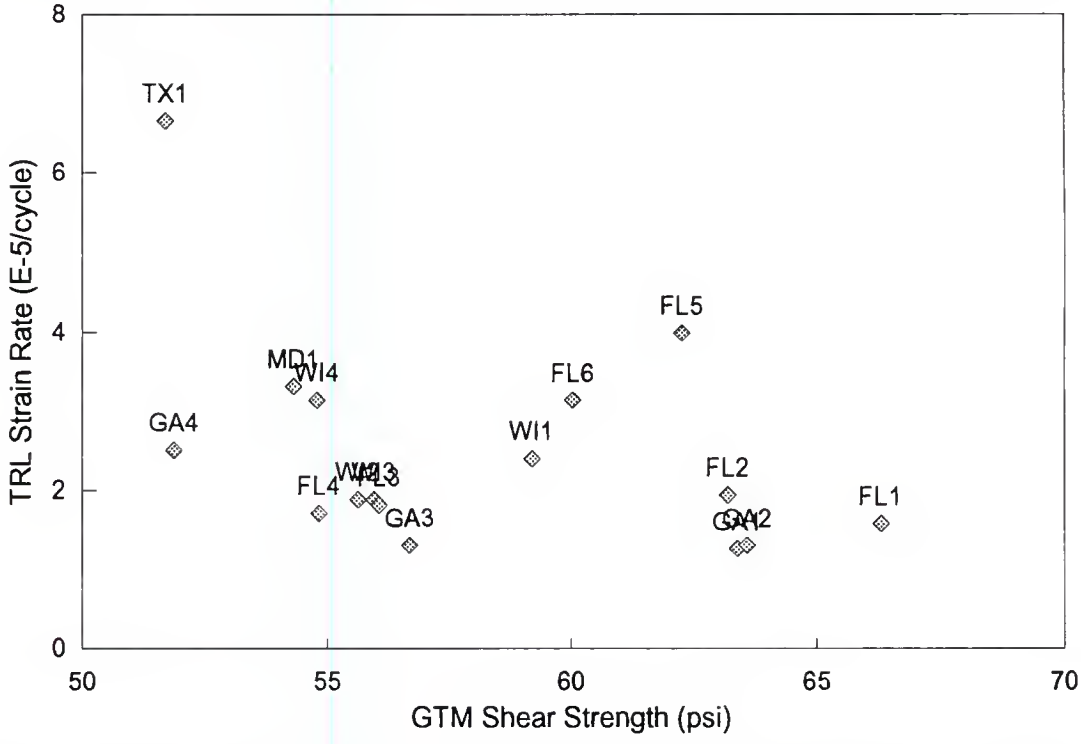

Figure 25. Plot of Shear Strength at 200 Gyrations versus TRL Permanent Strain Rate

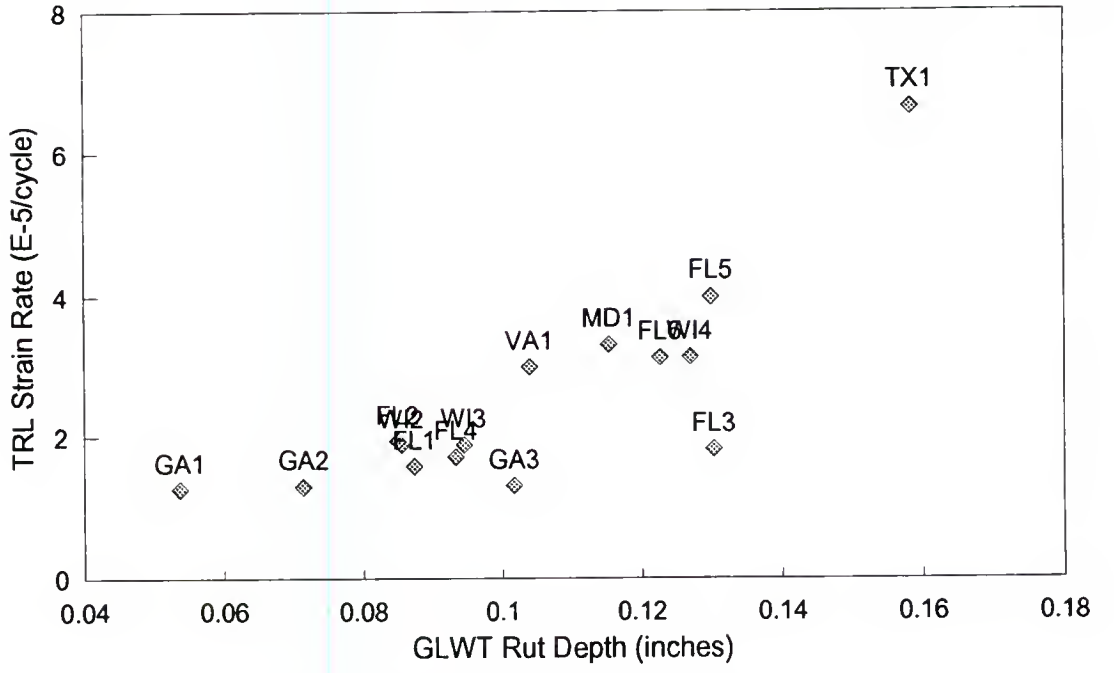

Figure 26. Plot of GLWT Rut Depth versus TRL Permanent Strain Rate

regression excluding the FL mixtures had an R^2 of 0.53. These two tests were expected to have a better correlation since they both utilize samples compacted in the GTM and are performed at the same temperature. The plot of GLWT rut depth versus TRL permanent strain rate, Figure 26, shows that higher rut depths correspond to higher strain rates. A second order regression indicated a good correlation with an R^2 of 0.92. A linear regression excluding the FL mixtures produced an R^2 of 0.78.

Table 15. Output of Rut Test Regressions

		All Mixtures		Excluding FL Mixtures	
X	Y	Equation	R^2	Equation	R^2
τG_{200}	Rut Depth	y = 0.314 - 0.004(x)	0.34	y = 0.489 - 0.007(x)	0.79
τG_{200}	ϵ_p rate	y = 10.0 - 0.13(x)	0.18	y = 20.3 - 0.31(x)	0.53
Rut Depth	ϵ_p rate	$y = 3.5-69.8(x)+561.7(x)^2$	0.92	y = -2.4 +49.56(x)	0.78

It is apparent from the regressions that the FL mixtures diminish the correlations involving GTM results. It is observed that FL5 and FL6 have higher shear strengths than may be expected from the results of the other tests. It is probable that the shear strengths for these two mixtures and possibly also FL1 are in error. The cause of such an error may have been due to improper alignment of the mold and sample in the GTM or incorrect readings of the air roller pressure gauge.

Exclusion of this maverick data does indicate a fairly good correlation between the different rutting tests. Also, comparison of results with previously reported criteria tend to indicate that most of the SMA mixtures have good rutting resistance. Results for all of the rutting tests indicate that GA1, GA2, and GA3 are very rut resistant. The very stiff low-density-polyethylene modified asphalt used in these mixtures probably provided a substantial increase in their deformation resistance. The excellent field performance for these mixtures also corroborates the test results. Each of the tests also indicate that mixture TX1 has marginal to poor rutting resistance. However, no field performance data is available for this mixture, even though it reportedly "appears" to be doing well.

6.7 Resilient Modulus Tests

Resilient Modulus results at 5, 25 and 40°C are shown in Table 16. Four results are reported for each mixture. The test was performed on duplicate samples, and on two diametrically orthogonal axes per sample. Analysis of variance was performed at each temperature to compare moduli of the different mixtures. Results of these analyses are

graphically illustrated in Figures 27, 28, and 29. Reasonably good coefficients of variation were obtained at each of the temperature conditions.

At low temperatures, a low elastic modulus is beneficial to prevent a rapid accumulation of tensile stresses and strains during temperature drops. However, the viscous element of the mixture's stiffness is more important to low temperature cracking. From Figure 27, it can be seen that the Florida experimental mixtures, except for FL5, have the lowest moduli. In diametral tests, the properties of the binder control mixture response. The low moduli of the experimental mixtures is probably due to the properties of the asphalt-rubber binder which permits greater elastic deformations.

Although rutting resistance is primarily dependent on the aggregate structure, the stiffness of the binder also plays a role in the mixture's deformation resistance. Therefore, at high temperatures, a higher stiffness (i.e. higher resilient modulus) is beneficial to minimize rutting. From Figure 29, it is evident that a wide range of moduli exist among the SMA mixtures. The three Georgia mixtures which have the highest resilient moduli all contain a very stiff modified asphalt.

Fatigue resistance of the SMA mixtures was evaluated with resilient moduli and tensile strain at failure using the technique presented in the AAMAS study [23]. This analysis is presented with the strain at failure data in section 6.8.

Plots of resilient moduli versus temperature are shown in Figures 30, 31 and 32. The reference lines, which extend the length of the graphs, are recommended upper and lower boundaries from the AAMAS study for dense-graded mixtures [23]. Figure 30

Table 16. Results of Resilient Modulus Tests

Mix I.D.	M_R at 5°C (ksi)	M_R at 25°C (ksi)	M_R at 40°C (ksi)
GA1	982 981 1051 1110	424 449 458 503	188 183 198 207
GA2	964 939 957 992	452 451 444 436	174 173 184 176
GA3	1128 1066 1178 1110	514 502 508 497	195 201 206 208
GA4	913 912 953 864	267 251 260 244	72 68 78 82
WI1	1293 1279 1227 1177	525 507 449 445	139 146 120 130
WI2	1080 1050 1017 997	394 369 357 345	103 100 109 118
WI3	1038 973 962 948	381 347 383 365	81 76 90 90
WI4	953 904 961 953	250 264 299 297	43 50 57 70
MD1	906 987 885 943	210 217 218 211	69 64 73 66
TX1	1038 1072 976 951	332 336 323 334	67 85 60 76
VA1	989 935 1022 992	273 256 270 261	88 81 81 92
FL1	809 905 752 848	375 370 373 370	115 117 105 101
FL2	952 858 916 912	362 363 387 353	85 90 94 98
FL3	941 875 845 812	342 330 308 292	60 74 66 72
FL4	774 766 787 775	308 307 328 319	100 92 92 89
FL5	1114 1040 1068 1035	359 357 358 355	85 92 83 93
FL6	868 855 863 890	215 222 241 244	57 59 64 68

General Linear Models Procedure

Dependent Variable: Total resilient modulus at 5°C

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	8.48 E+11	5.3 E+10	45769.4	25.30	0.0001

$\alpha = 0.05$
R-Square = 0.888
C.V. = 4.664

Duncan Grouping

Means with the same letter are not significantly different

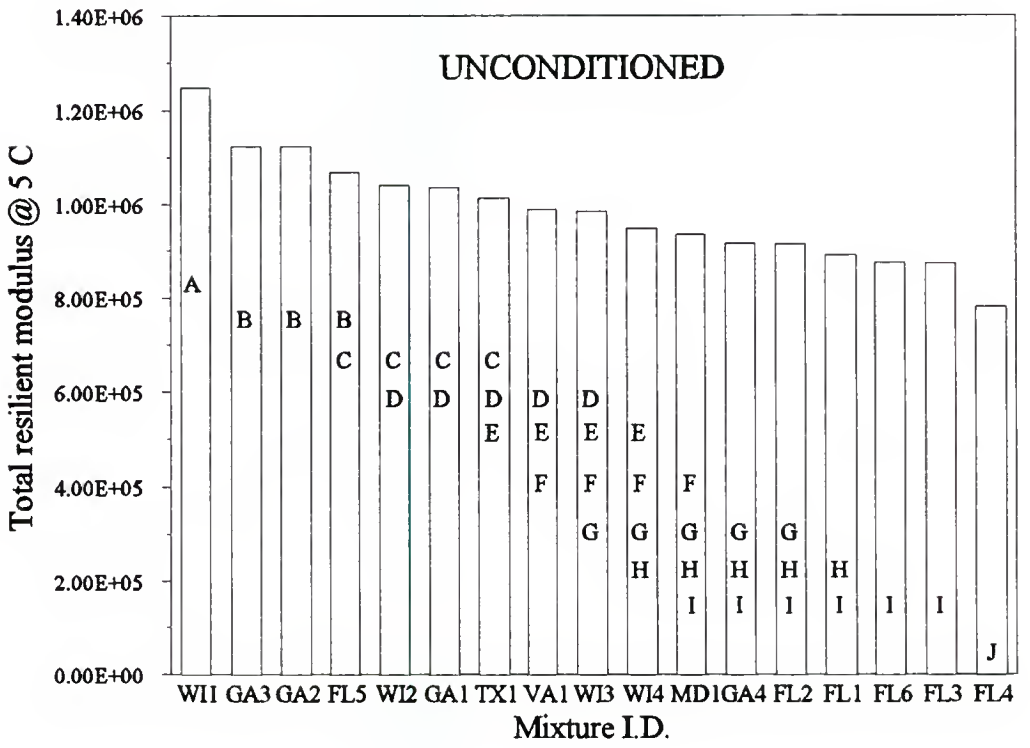
UNCONDITIONED
Total resilient modulus @ 5 C
1.40E+06
1.20E+06
1.00E+06
8.00E+05
6.00E+05
4.00E+05
2.00E+05
0.00E+00
A
B B B C C D C D C D E D E F D E F G E F G H F G H I G H I G H I H I I I J
WI1 GA3 GA2 FL5 WI2 GA1 TX1 VA1 WI3 WI4 MD1 GA4 FL2 FL1 FL6 FL3 FL4
Mixture I.D.

Figure 27. Comparison of Low Temperature Resilient Moduli

General Linear Models Procedure

Dependent Variable: Total resilient modulus at 25 °C

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	5.5 E+11	3.44 E+10	19491.8	90.45	0.0001

$\alpha = 0.05$
R-square = 0.963
C.V. = 5.582

Duncan Grouping

Means with the same letter are not significantly different

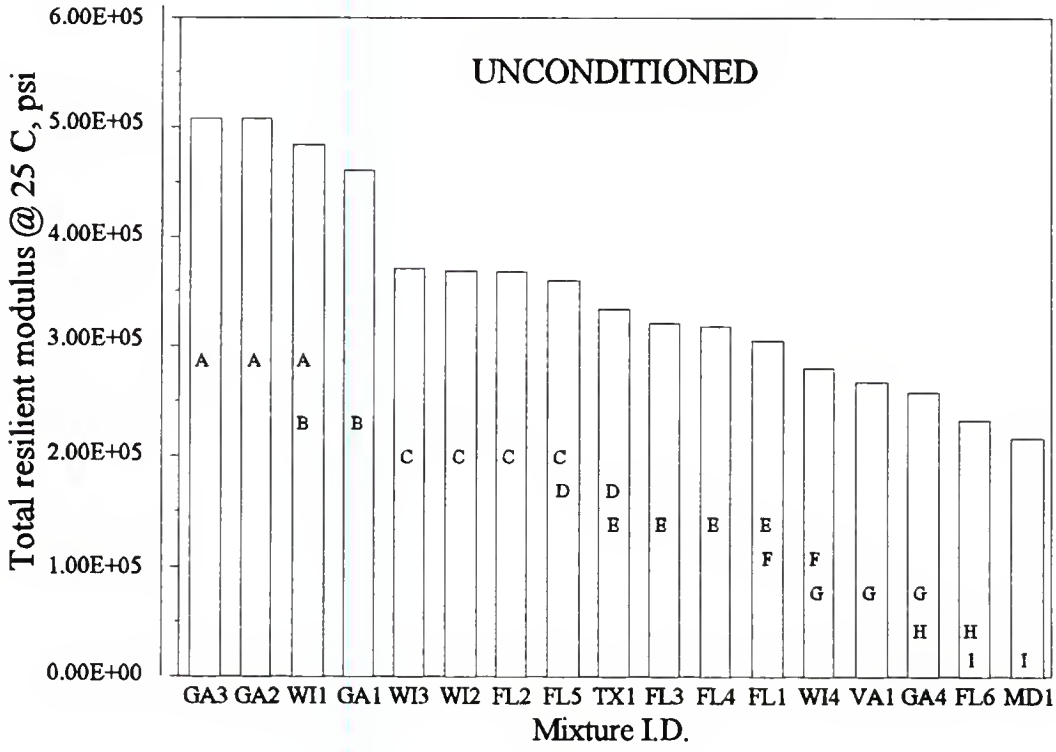
UNCONDITIONED
Total resilient modulus @ 25 C, psi
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.00E+00
A A A B B C C C C D D E E E E F F G G G H H I I
GA3 GA2 WI1 GA1 WI3 WI2 FL2 FL5 TX1 FL3 FL4 FL1 WI4 VA1 GA4 FL6 MD1
Mixture I.D.

Figure 28. Comparison of 25°C Resilient Moduli

General Linear Models Procedure

Dependent Variable: Total resilient modulus at 40 °C

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	1.41 E+11	8.81 E+09	7437.97	159.26	0.0001

$\alpha = 0.05$
R-Square = 0.981
C.V. = 7.340

Duncan Grouping

Means with the same letter are not significantly different

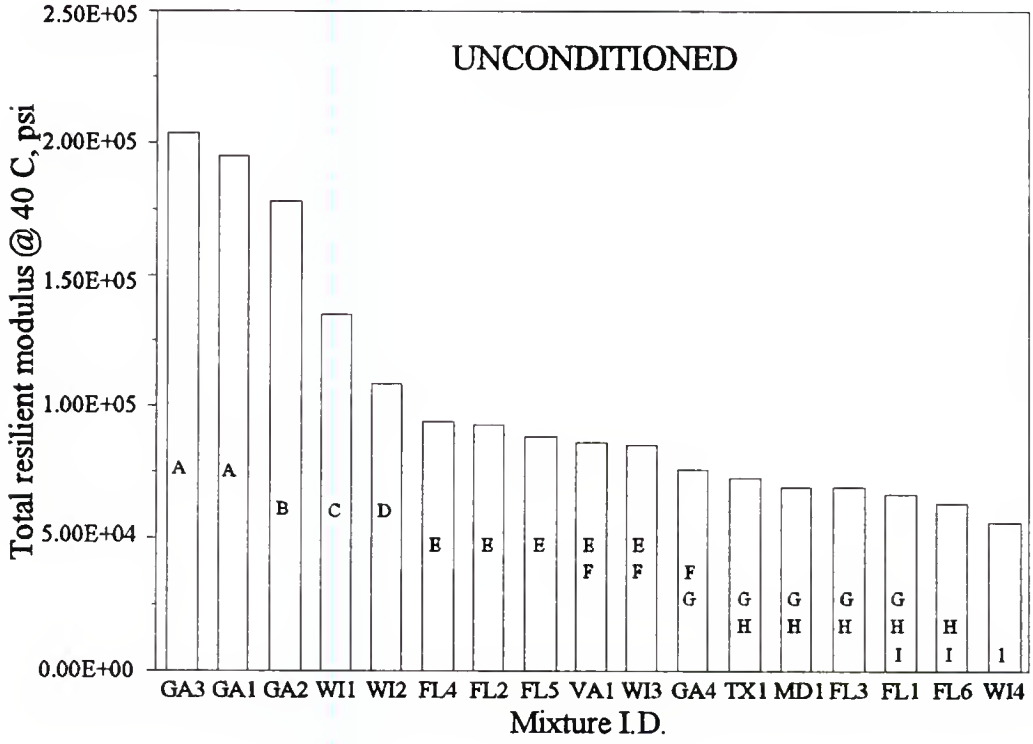

Figure 29. Comparison of 40°C Resilient Moduli

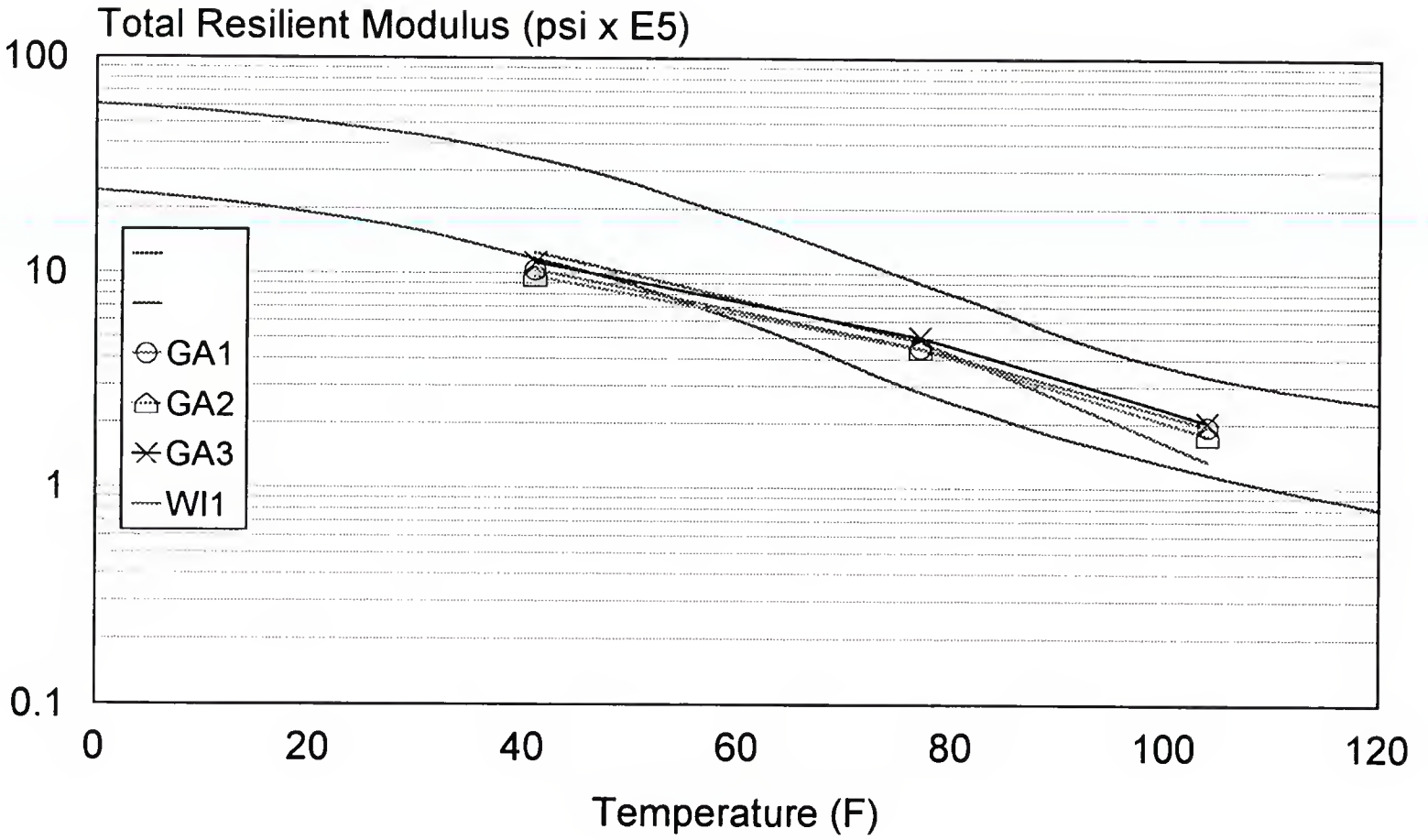

Figure 30. Plot of Resilient Moduli versus Temperature for Mixtures GA1, GA2, GA3, and WI1

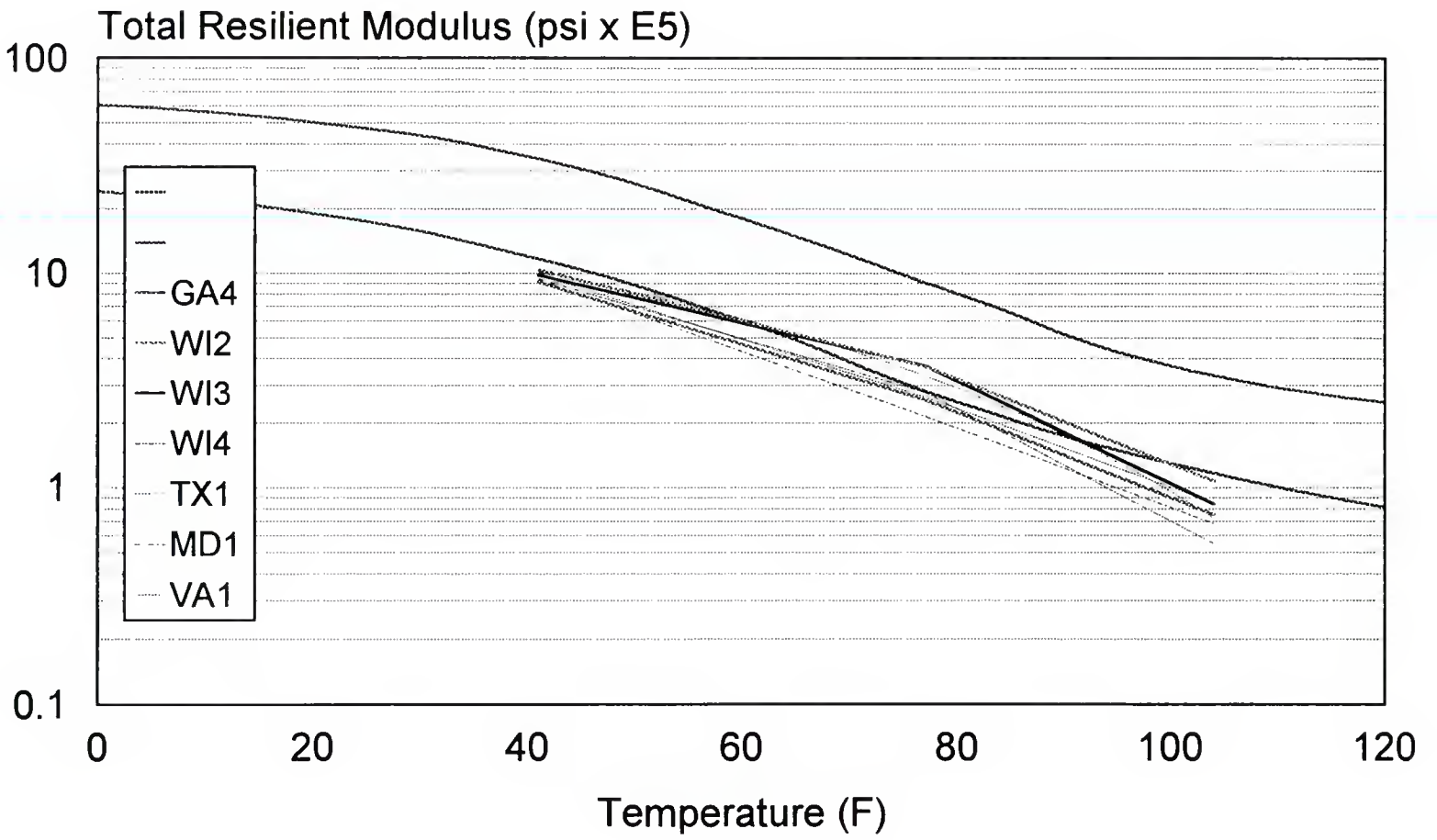

Figure 31. Plot of Resilient Moduli versus Temperature for Field Mixtures with Relatively Low Stiffnesses

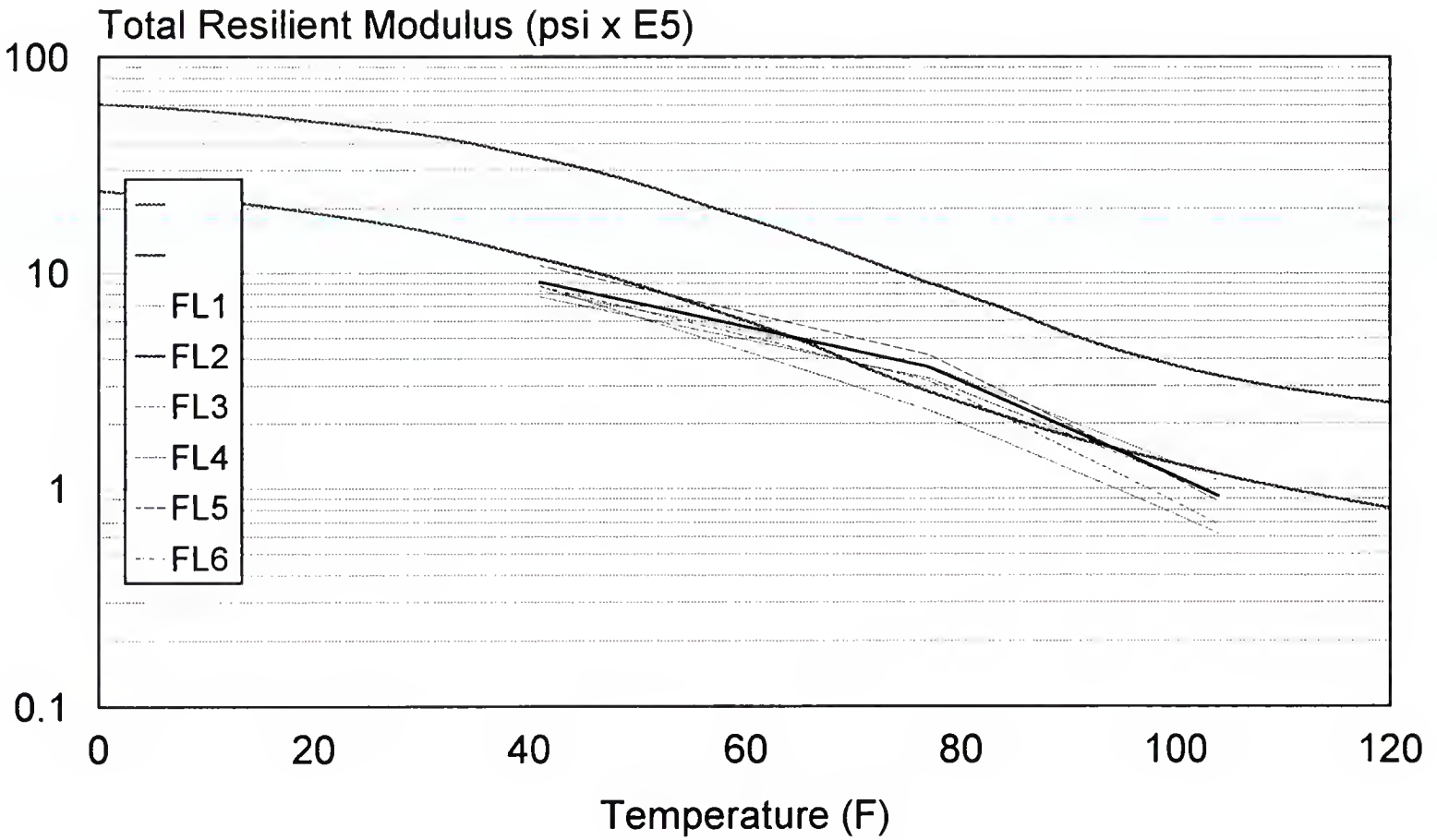

Figure 32. Plot of Resilient Moduli versus Temperature for Florida Experimental Mixtures

includes several mixtures that are within or on the lower boundary. Little's work [22] with mixtures GA1 and GA2 found very similar results at the low and intermediate temperatures. However, his data at 40°C for GA1 and GA2 show the moduli below the lower boundary. Figure 31 shows that most of the SMA mixtures fall just below the lower dense-graded boundary, with a pronounced drop in moduli at the high temperature as was observed by Little. Although Little concluded that this behavior is due to the lack of mixture confinement of SMA mixtures in the diametral mode, it is also plausible the lower moduli are simply due to the thicker binder film thicknesses of SMA mixtures which tend to react to tensile stresses with higher strains.

6.8 Indirect Tensile Strength Tests

Results of the indirect tensile strength tests are shown in Table 17. Reported are tensile strengths, horizontal strains at failure, and fracture energy. This test was performed at 25°C on samples which had previously been tested in the diametral creep test. It can be seen that the air void content of the samples affects their tensile strength. However, strain at failure is apparently not affected by air void content.

Comparisons of tensile strengths for all of the test mixtures are shown in Figure 33. This data again shows the effect of the stabilizing additives, Mixtures GA1, GA2, and GA3 contain a polyethylene modified asphalt and mineral fibers. This combination apparently significantly enhances tensile strength and as noted later, reduces the failure strains. All of the Florida experimental mixtures contain ground tire rubber as the stabilizing additive. Most of these mixtures have similar tensile strengths. The low tensile strengths for MD1 may be due to damage of these specimens during the creep tests.

Table 16. Results of Indirect Tensile Strength Tests

Mix I.D.	Air Voids (%)	Tensile Strength (psi)	Strain at Failure (%)	Fracture Energy (psi)
GA1	3.7 4.3	200.0 176.3	0.53 0.43	2.02 1.46
GA2	6.3 5.2	178.0 209.0	0.49 0.50	1.66 2.00
GA3	5.8 6.3	161.7 185.5	0.49 0.49	1.58 1.75
GA4	5.7 6.3	153.7 139.0	1.10 1.08	3.20 2.87
WI1	7.2 7.5	177.6 165.0	0.47 0.45	1.60 1.41
WI2	10.1 9.9	156.3 156.1	0.45 0.67	1.35 2.02
WI3	6.6 6.5	114.4 107.3	1.09 0.91	2.42 1.87
WI4	6.4 6.0	112.3 135.1	0.77 0.57	1.68 1.50
MD1	7.1 6.1	52.7 80.2	1.55 1.19	1.56 1.85
TX1	7.0 7.3	117.5 101.3	1.30 1.25	2.93 2.48
VA1	5.9 6.4	126.0 112.6	0.90 1.06	2.18 2.31
FL1	6.8 8.5	168.4 150.1	0.56 0.59	1.81 1.73
FL2	7.4 7.3	124.0 148.6	0.51 0.58	1.23 1.64
FL3	6.7 6.8	107.3 107.5	0.64 0.82	1.31 1.71
FL4	6.0 6.1	129.0 129.3	0.54 0.54	1.33 1.33
FL5	6.1 5.7	129.4 133.2	0.71 0.67	1.75 1.85
FL6	7.4 7.5	124.6 119.9	0.68 0.78	1.60 1.77

General Linear Models Procedure

Dependent Variable: Indirect tensile strength, psi

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	34719.47	2169.97	12.39	14.13	0.0001

$\alpha = 0.05$
R-Square = 0.930
C.V. = 8.985

Duncan Grouping

Means with the same letter are not significantly different

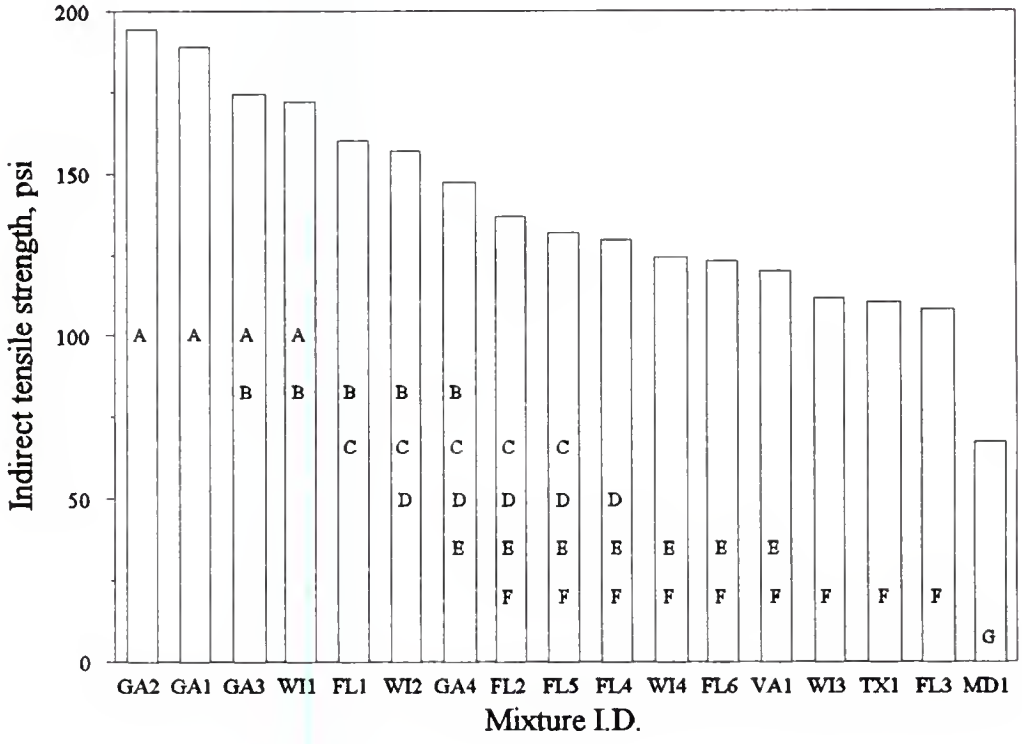
Indirect tensile strength, psi
200
150
100
50
0
A A A A B B B C B C D B C D E C D E F C D E F D E F E F E F F F F G
GA2 GA1 GA3 WI1 FL1 WI2 GA4 FL2 FL5 FL4 WI4 FL6 VA1 WI3 TX1 FL3 MD1
Mixture I.D.

Figure 33. Comparison of Tensile Strengths

Comparisons of the failure strains are shown in Figure 34. Although the three Georgia (GA1, GA2, and GA3) mixtures with polyethylene modified asphalt and mineral fibers have very high tensile strengths, the relatively low failure strains indicate that these mixtures may tend to be brittle. Some of the other additives apparently have more affect on strain to failure than on tensile strength. The two mixtures containing cellulose fibers, TX1 and VA1, have among the highest failure strains. The ability of these mixtures to deform more before failure is probably due to the higher asphalt contents afforded by the use of cellulose fibers. Other mixtures with modified binders, such as GA4 which contains cellulose fibers and an SBS modified asphalt, and WI3 which contains an unknown modifier, also yielded high failure strains.

An evaluation of fatigue cracking potential for each of the mixtures was made by plotting the failure strains and the resilient moduli at 25°C on the fatigue chart given in the AAMAS study [23]. These plots are shown in Figures 35 through 38. Lines representing two standard fatigue relationships used in the AAMAS study are shown in the charts. Mixtures which plot above these lines are considered to have satisfactory fatigue resistance.

It can be seen that most of the SMA mixtures do not meet the criteria which were developed for conventional dense-graded mixtures. Obviously, those mixtures that do plot above the minumum fatigue lines (MD1, TX1, GA4, AND WI3) are the mixtures with higher failure strains, generally about 0.9 percent (9 mils/inch) or greater. Failure of most of the SMA mixtures to meet the DGAC criteria was unexpected since it is generally percieved that the rich SMA mastics would be more durable and resistant to cracking.

General Linear Models Procedure

Dependent Variable: Strain at failure, %

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	2.68	0.1675	0.099	16.77	0.0001

$\alpha = 0.05$
R-Square = 0.940
C.V. = 13.42

Duncan Grouping

Means with the same letter are not significantly different

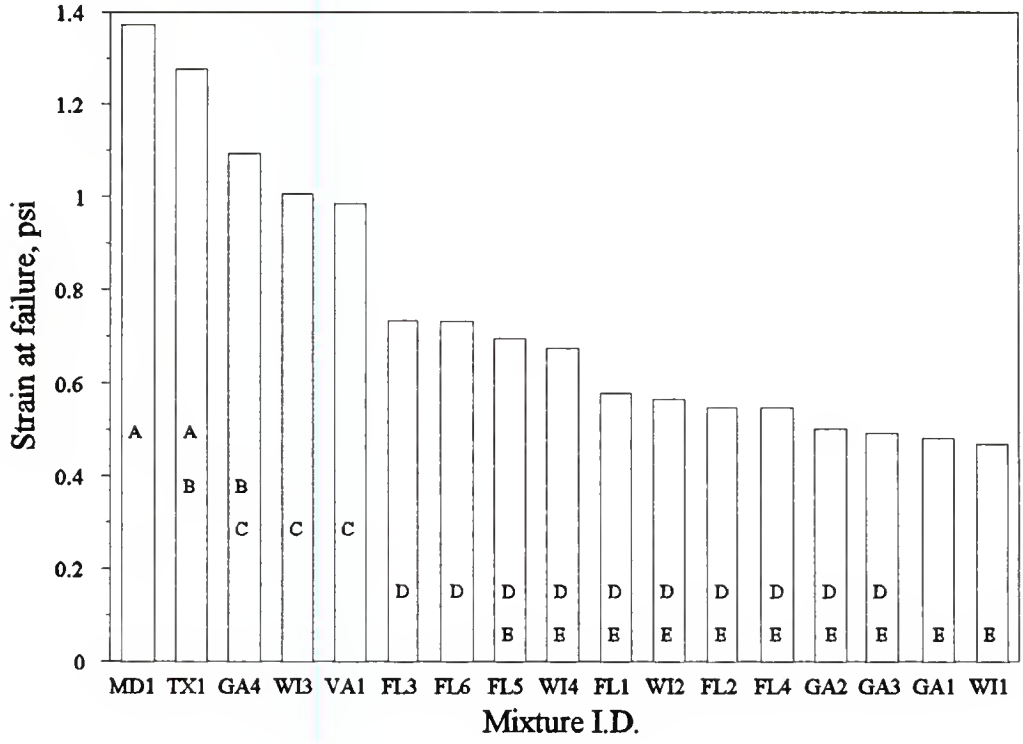

Figure 34. Comparison of Failure Strains

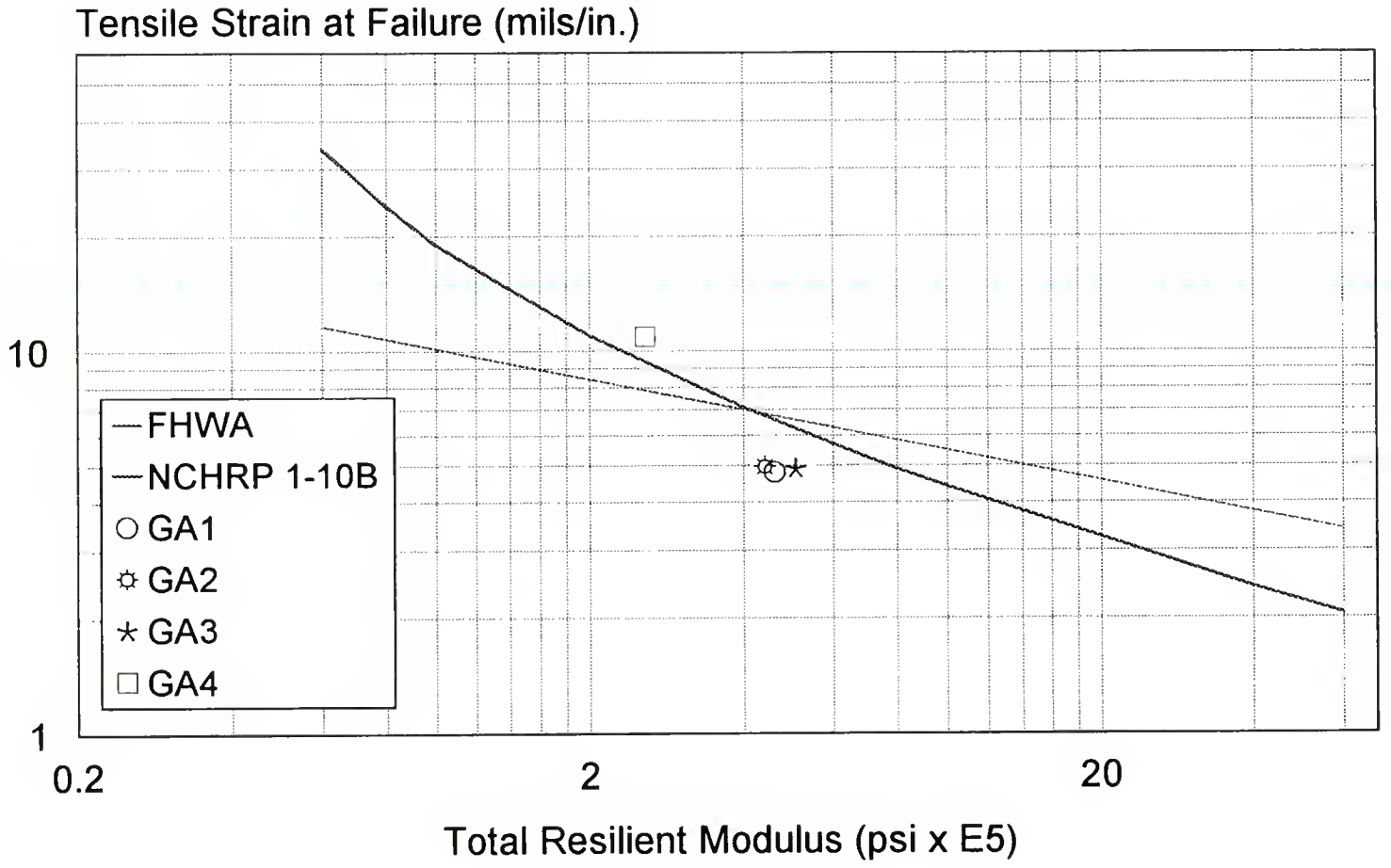

Figure 35. Plot of Georgia SMA Mixtures on the AAMAS Fatigue Chart

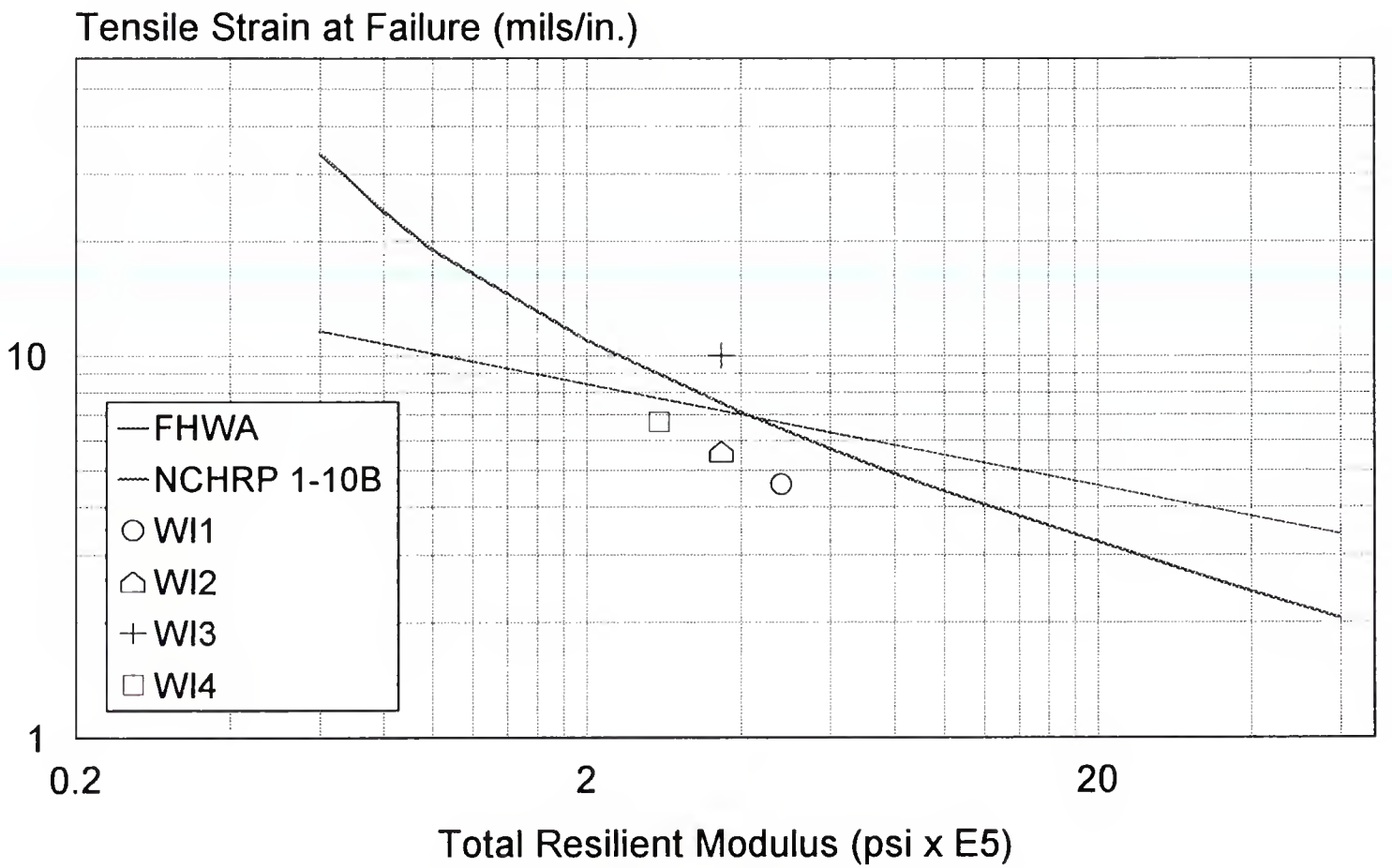

Figure 36. Plot of Wisconsin SMA mixtures on the AAMAS Fatigue Chart

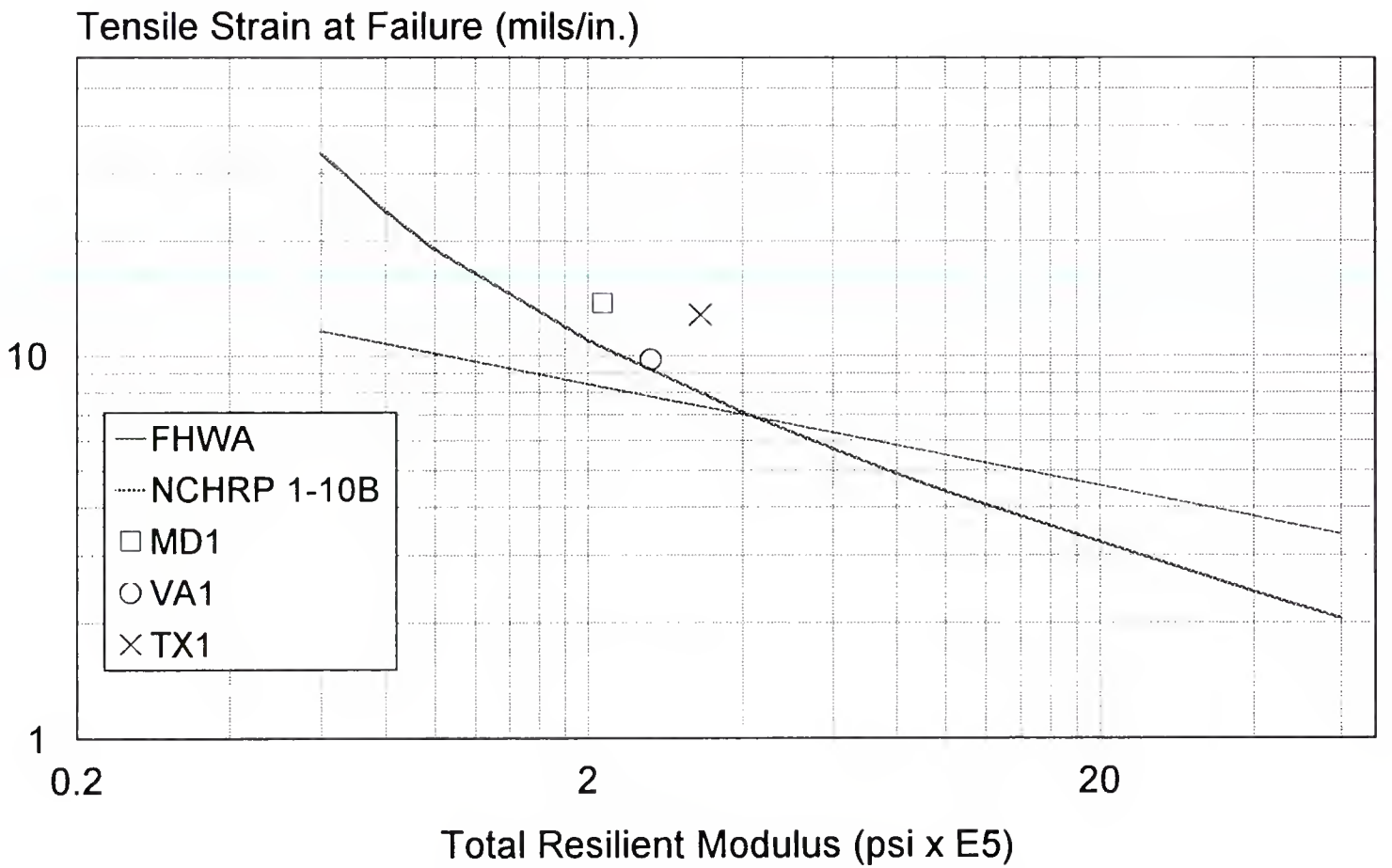

Figure 37. Plot of Maryland, Virginia and Texas SMA Mixtures on the AAMAS Fatique Chart

Figure 38. Plot of the Florida Experimental SMA Mixtures on the AAMAS Fatigue Chart

The criteria for evaluation of SMA mixtures may need to be adjusted. As shown in the resilient modulus versus temperature plots in section 6.7, the moduli for SMA mixtures were generally at or below the margin of values typical of dense-graded mixtures. Further research is needed to determine the applicability of the resilient modulus tests and associated criteria for SMA mixtures.

As a final note, the fatigue potential of SMA mixtures is a relatively minor concern due to the fact that these mixtures are usually the surface layer of heavy-duty pavement structures where the tensile stresses due to loading are relatively low.

6.9 Diametral Creep Tests

Results of the diametral creep tests are shown in Table 17. Creep compliance values at five periods are reported. Also shown is the percentage of the total horizontal deformation that was recovered after the load was released.

It can be seen that the creep compliance values were generally not repeatable for duplicate samples. Close examination of the data reveals that most of the difference between duplicate samples occurs in the initial values, and that after the initial data, the changes in compliance are a little more consistent. The cause of the initial differences may have been due to the initial sudden application of the creep load which could have caused further seating of the loading strips or slippage of the horizontal extensometer on some samples.

Table 17. Results of Diametral Creep Tests

Mix I.D.	Air Voids (%)	Creep Compliance at 1 sec. (1/psi E-5)	Creep Compliance at 10 sec. (1/psi E-5)	Creep Compliance at 100 sec. (1/psi E-5)	Creep Compliance at 500 sec. (1/psi E-5)	Creep Compliance at 1000 sec. (1/psi E-5)	Percent Recovery (%)
GA1	3.7	6.03	6.44	6.98	7.59	7.74	71.2
	4.3	2.51	2.80	3.24	3.85	4.06	59.8
GA2	6.3	2.27	2.49	2.87	3.38	3.57	96.2
	5.2	1.73	1.91	2.17	2.57	2.69	54.5
GA3	5.8	1.88	2.07	2.37	2.73	2.89	50.5
	6.3	1.60	1.75	2.05	2.46	2.65	98.3
GA4	5.7	2.82	3.21	3.81	4.54	4.85	72.6
	6.3	1.86	2.15	2.69	3.43	3.71	64.0
WI1	7.2	2.87	3.03	3.25	3.52	3.61	57.9
	7.5	2.12	2.29	2.51	2.81	2.89	55.0
WI2	10.1	3.19	3.39	3.64	3.91	3.98	37.4
	9.9	1.72	1.92	0.22	2.58	2.74	46.0
WI3	6.6	3.34	3.77	4.44	5.30	5.69	35.6
	6.5	2.44	2.82	3.32	3.88	4.10	72.5
WI4	6.4	4.48	4.93	5.57	6.27	6.49	58.4
	6.0	4.84	5.28	5.95	6.93	7.11	88.4
MD1	7.1	4.77	5.43	6.54	8.27	8.84	58.1
	6.1	2.53	2.99	3.68	4.50	4.96	85.2
TX1	7.0	4.38	4.64	5.08	5.74	6.00	60.6
	7.3	1.73	1.88	2.19	2.71	2.99	39.0
VA1	5.9	5.24	5.64	6.26	7.05	7.31	75.3
	6.4	2.93	3.20	3.74	4.71	5.11	79.7
FL1	6.8	2.13	2.36	2.73	3.24	3.42	72.0
	8.5	1.74	1.94	2.26	2.75	2.96	66.3
FL2	7.4	3.50	3.94	4.51	5.07	5.26	76.2
	7.3	3.24	3.50	3.92	4.51	4.74	68.3
FL3	6.7	1.55	1.76	2.13	2.74	3.07	64.0
	6.8	1.73	1.96	2.43	3.30	3.69	63.6
FL4	6.0	3.91	4.31	5.01	5.92	6.29	36.0
	6.1	3.32	3.67	4.25	5.09	5.32	60.9
FL5	6.1	2.11	2.33	2.68	3.19	3.42	38.2
	5.7	2.75	3.02	3.48	4.12	4.37	64.5
FL6	7.4	2.66	2.87	3.28	5.0	4.11	93.4
	7.5	4.97	5.40	6.04	5.2	7.19	91.9

Regardless of the inital creep compliance data, the important data for evaluating low temperature cracking potential is the slope of creep curve. From the creep compliance versus time plots it was evident that the slope did not reach a constant value until approximately half-way through the loading period. The slopes of the creep compliance curves were therefore taken between 500 and 1000 seconds.

Comparisons of the creep compliance slopes are shown in Figure 39. The mixtures with the lowest creep compliance slopes were WI1 and WI2, followed by GA2, GA1, and GA3. Since the slope of the creep compliance curve is inversely related to the viscous stiffness of the mixture, a low creep compliance slope indicates that contraction of the pavement during a temperature drop would cause an accumulation of tensile stresses and elastic strains. Conversely, a mixture with higher creep compliance slope (i.e. low viscous stiffness) would strain more through viscous deformation and not build up tensile stresses. Therefore, WI1, WI2, GA2, GA1, and GA3 would appear to have greater potential for thermal cracking than mixtures with higher creep compliance slopes such as VA1, FL3, and WI3.

The creep behavior of asphalt mixtures is primarily controlled by the viscoelastic nature of the binder. Therefore, it is not surprising that the stabilizing additives which tend to stiffen the binder, such as the Novophalt binder in GA1, GA2, and GA3, and the Vestoplast in WI1 and WI2, resulted in lower creep compliance slopes. However, MD1, which also contained Vestoplast had the highest creep compliance slope among the study mixtures. It is suspected that the MD1 samples were damaged during the initial trial testing of the creep procedure to establish the appropriate static load. The initial tests of

General Linear Models Procedure

Dependent Variable: Slope of creep compliance (1/ksi x E-9)

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	134.15	8.38	1.14	6.42	0.0002

$\alpha = 0.05$
R-Square = 0.858
C.V. = 23.16

Duncan Grouping

Means with the same letter are not significantly different

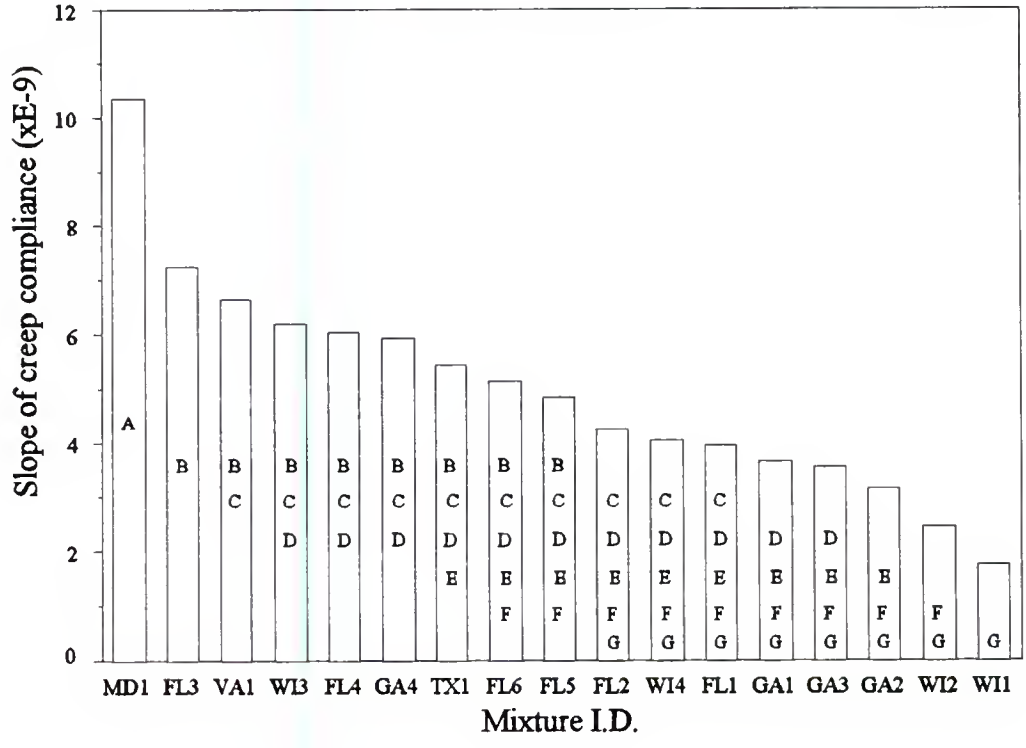

Figure 39. Comparison of Creep Compliance Slopes

the MD1 samples at a higher load caused tertiary type horizontal deformations and small cracks were evident in the samples near the loading strip. Subsequent tests performed at lower loads did not appear to cause tertiary type deformations.

Mixtures containing other additives such as SBS, cellulose fibers and ground tire rubber generally had higher creep compliance slopes. However, it is not possible to distinguish of any of the additives consistently provides a clear advantage with respect to low temperature due to the variablity in the results and the influence of other variables.

6.10 Moisture Damage Tests

Two tests were used to evaluate the potential for moisture damage of the SMA mixtures: MRR, the ratio of resilient moduli after moisture conditioning to before conditioning, and TSR the ratio of tensile strengths of moisture conditioned samples to unconditioned samples. Results of these tests are shown in Table 18.

For several mixtures some of the ratios appear to indicate erroneous data. It is unexpected to have ratios greater than 100. A hypothesis for the cause of these unexpected results is that water trapped in the sample during the moisture conditioning procedure created negative pore pressure (tension) during the rapid loading of the resilient modulus test. It would be less likely for this to occur in the much slower loading rate of the indirect tension test.

For modulus testing, it is recommended that the tests begin at the low temperature first, then the middle temperature and the high temperature last to reduce to chance of sample damage. This guideline was not followed during testing of the mositure conditioned samples due to a failure to get a timely delivery of the liquid nitrogen for

Table 18. Moisture Damage Test Results

Mix I.D.		GA1	GA2	GA3	GA4	WI1	WI2	WI3	WI4	MD1	TX1	VA1	FL1	FL2	FL3	FL4	FL5	FL6
Air Voids (%)		4.2	6.9	6.5	6.1	7.7	9.2	5.4	4.9	6.5	6.5	4.9	5.7	7.3	6.4	5.5	6.0	6.9
Saturation (%)		65	65	63	61	54	100	63	68	62	66	73	60	99	99	95	60	67
5 C Resilient Modulus (ksi)	U	1031	963	1120	910	1244	1036	980	943	930	1009	984	829	909	868	775	1065	869
	C	929	900	1060	829	1005	859	889	913	923	928	926	813	684	819	722	1011	839
	Ratio	90	93	95	91	81	83	91	97	99	92	94	98	75	94	93	95	97
25C Resilient Modulus (ksi)	U	459	446	505	258	482	366	369	278	214	331	265	372	366	318	315	357	231
	C	509	473	519	299	438	288	339	268	231	302	324	462	251	253	280	343	220
	Ratio	111	106	103	117	91	79	92	96	108	91	122	124	69	80	89	96	95
40 C Resilient Modulus (ksi)	U	194	177	203	75	134	107	84	55	68	72	85	109	92	68	93	87	62
	C	169	148	142	66	110	71	89	50	63	58	72	105	59	46	73	76	47
	Ratio	87	84	70	88	82	66	106	91	93	81	85	96	64	68	78	87	76
Indirect Tensile Strength (psi)	U	188	194	174	147	165	156	111	124	80	109	119	159	136	107	129	131	122
	C	157	142	144	130	163	110	119	101	93	90	110	103	96	98	94	126	85
	Ratio	83	74	83	89	99	71	107	82	116	82	92	64	71	91	73	96	70

U= unconitioned, C= conditioned

cooling of the test chamber. When the samples had been moisture conditioned, the gas supplier could not replace the nitrogen tank until the next day, and therefore the modulus tests were started at 25°C. That is why the ratios for many mixtures are higher at 25°C than the other temperatures. By the time the samples completed preheating for the 40°C tests most of the pore water had probably evaporated.

Therefore, the 40°C MRR's and 25°C TSR's were considered the most useful for evaluating moisture damage potential. Using these results and the generally used criteria of 80 percent minimum MRR or TSR, most of the mixtures appear to have adequate moisture damage resistance. Comparisons of Resilient Modulus Ratios are shown in Figure 40. Statistical comparisons of tensile strength ratios were not possible since TSR is based on the average of the unconditioned set and conditioned set, rather than on individual samples. Mixtures which are susceptable to moisture damage include WI2, FL2, FL4, and FL6. Moisture damage to WI2 was more likely due to the very high air void content of this mixture. FL2, a Florida limestone mixture, would not be expected to be susceptable to moisture damage based on the history of this aggegate in dense-graded mixtues, but broken aggregates and dusty particles may have weakened the mixture. FL4, the crushed PCC mixture, and FL6, the crushed river gravel mixture, were more likely to experience moisture damage due to the surface chemistry of the aggregate.

MRR and TRR results are contradictory for several mixtures: GA3, FL1, FL3, and FL5. Consequently, characterising the moisture damage potential for these mixtures is difficult. All of the Florida experimental mixtures except FL1 had MRR values below 80

General Linear Models Procedure

Dependent Variable: Resilient modulus ratio at 25 °C

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	16	0.6927	0.04329	0.076	7.52	0.0001

$\alpha = 0.05$
R-Square = 0.876
C.V. = 7.804

Duncan Grouping

Means with the same letter are not significantly different

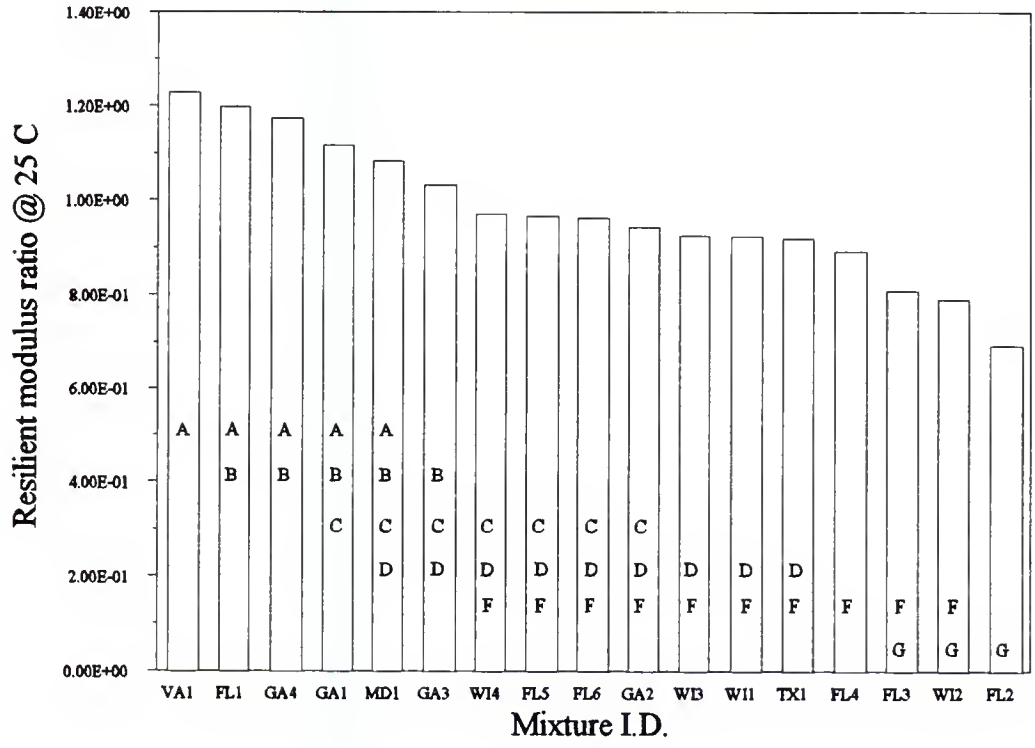

Figure 40. Comparison of Resilient Modulus Ratios

percent. An antistripping additive was not used with these mixtures. It is probable that adding an antistripping agent would improve the ratios for these mixtures.

CHAPTER 7
SMA AGGREGATE CHARACTERISTICS AND TEST METHODS

7.1 The Aggregate Issues

Aggregate quality has been an important and controversial issue in the transfer of the SMA technology from Europe to the U.S. Most references state that SMA aggregates should be only high-quality, tough and angular aggregates. The implication being that many of the current aggregates used in DGAC mixtures are not suitable for use in SMA mixtures. This section provides a review of important aggregate characteristics and a discussion of why or if SMA aggregates need to be of higher quality.

7.2 Review of Desired Aggregate Characteristics

Aggregate characteristics play a major role in the performance of asphalt-aggregate mixtures. Some of the characteristics which are most often cited are: aggregate gradation, particle strength, particle shape, cleanliness, soundness, absorptiveness, surface texture, wear resistance, and affinity for asphalt [44,45]. Generally, these aggregate characteristics are important to the mixture behavior and/or durability regardless of whether it is dense-graded or an SMA. Some characteristics, however, become more critical to mixture performance based on the mixture type and its use or purpose. For instance, the wear characteristics (i.e., polish resistance) of aggregates are of paramount importance for surface mixtures which are intended to provide high skid resistance, but

have essentially no effect on how aggregates perform in structural pavement layers or base course mixtures.

Table 19 summarizes general ratings of the most common rock types with respect to engineering properties. Table 20 includes the same general rock types rated specifically for use in asphalt mixtures.

Table 19. Summary of Engineering Properties of Rocks [46]

Type of Rock	Mechanical Strength	Durability	Chemical Stability	Surface Characteristics	Presence of Undesirable Impurities
Igneous:					
Granite, syenite, diorite	Good	Good	Good	Good	Possible
Felsite	Good	Good	Questionable	Fair	Possible
Basalt, diabase, gabbro	Good	Good	Good	Good	Seldom
Peridotite	Good	Fair	Questionable	Good	Possible
Sedimentary:					
Limestone	Good	Fair	Good	Good	Possible
Sandstone	Fair	Fair	Good	Good	Seldom
Chert	Good	Poor	Poor	Fair	Likely
Conglomerate, breccia	Fair	Fair	Good	Good	Seldom
Shale	Poor	Poor	Poor	Good	Possible
Metamorphic:					
Gneiss, schist	Good	Good	Good	Good	Seldom
Quartzite	Good	Good	Good	Good	Seldom
Marble	Fair	Good	Good	Good	Possible
Serpentinite	Fair	Fair	Good	Fair to poor	Possible
Amphibolite	Good	Good	Good	Good	Seldom
Slate	Good	Good	Good	Poor	Seldom

Table 20. Ratings for General Characteristics of Rock Types for Use in Asphalt Mixtures [47]

Rock Type	Hardness, Toughness	Resistance to Stripping	Surface Texture	Crushed Shape
Igneous:				
Granite	Fair	Fair	Fair	Fair
Syenite	Good	Fair	Fair	Fair
Diorite	Good	Fair	Fair	Good
Basalt (trap rock)	Good	Good	Good	Good
Diabase (trap rock)	Good	Good	Good	Good
Gabbro (trap rock)	Good	Good	Good	Good
Sedimentary:				
Limestone, dolomite	Poor	Good	Good	Fair
Sandstone	Fair	Good	Good	Good
Chert	Good	Fair	Poor	Good
Shale	Poor	Poor	Fair	Fair
Metamorphic:				
Gneiss	Fair	Fair	Good	Good
Schist	Fair	Fair	Good	Fair
Slate	Good	Fair	Fair	Fair
Quartzite	Good	Fair	Good	Good
Marble	Poor	Good	Fair	Fair
Serpentinite	Good	Fair	Fair	Fair

7.3 Aggregate Characteristics Related to Shear Strength

The importance of many aggregate characteristics can easily be visualized by considering the effects on mixture shear strength. The Mohr-Coulomb theory developed in soil mechanics can also be used to fundamentally describe the shear strength of asphalt-aggregate mixtures. According to the Mohr-Coulomb theory, shear strength is derived from a combination of interparticle bonds, expressed as cohesion, and frictional resistance between soil (or aggregate) particles [48]. The Mohr-Coulomb theory is often expressed algebraically as:

$$\tau = c + \sigma \tan\phi \quad (10)$$

where:

τ = shear strength
c = cohesion
σ = normal stress
ϕ = friction angle.

7.3.1 Cohesion

For asphalt mixtures, cohesion can be considered dependent on the asphalt binder and the ability of the asphalt to bond to the aggregates. Although aggregates without asphalt have no cohesion, aggregate characteristics such as surface texture, absorption, cleanliness, and mineralogy directly affect how well the asphalt adheres to the aggregate. Asphalt films tend to adhere better to aggregates with rough, porous aggregate surfaces to which the asphalt can penetrate and establish a mechanically bonded interface. Aggregate cleanliness is important because dust coatings on aggregate surfaces interfere with the ability of the asphalt to adhere to the aggregate. Mineral composition of aggregates is one of the most important factors which affects the strength of the asphalt-aggregate bond, particularly in the presence of water. Siliceous aggregates are generally considered hydrophilic (water loving) because they possess a negative surface charge that is more easily satisfied by water than asphalt. Under some circumstances, water or water vapor in the pavement can penetrate the asphalt coating on siliceous aggregates and displace the film from the aggregate surface and result in a loss of mixture cohesion.

7.3.2 Frictional Resistance

As shown in Equation 10, frictional resistance is the product of the normal stress and the coefficient of friction (i.e. tanϕ). Frictional resistance in an asphalt mixture is developed through the summation of friction between many points of contact between aggregate particles. Normal stress is proportional to the relative density of the mixture and external forces applied to the mixture. Although density is controlled primarily by the compactive effort, it is also dependent to a great degree on the aggregate gradation. Gradation also controls the number of contacts between aggregate particles. Open-graded mixtures, which generally contain a narrow size range of coarse aggregates, have relatively few points of contact per particle. Dense arrangements of aggregate particles can be achieved by well-graded blends containing a complete distribution of particle sizes, or by a gap gradation in which coarse aggregate particles fit tightly together and properly sized fine size particles fill in spaces between the larger particles. Since contacts between particles occur at discrete sites, forces are distributed through small areas of contact. Fewer points of contact within a gradation increases the contact stresses and can cause crushing or fracturing of particles.

The friction angle, ϕ, is dependent primarily upon characteristics of the aggregate such as particle shapes, surface texture and gradation. The friction angle of an aggregate mass is inversely related to how easily particles slide on one another. Smooth, rounded particles slide more easily than rough textured, angular particles. Therefore, a higher friction angle and greater shear strength can be achieved using angular shaped aggregates with rough textured surfaces.

The significance of the shear strength concept is that it helps explain why SMA mixtures may be more rut resistant and why aggregate strength may be more critical for SMA mixtures. Rutting associated with instability of the asphalt layer(s) is due to the accumulation of non-recoverable shear deformations in the asphalt mixture(s). SMA mixtures are believed to be more resistant to rutting because they are more resistant to shear deformations. The increased resistance to shear deformation is attributed to greater frictional resistance developed by interlocking of the coarse aggregate particles. For any strain or deformation of the mixture to occur, relative movements must also occur at the aggregate contacts. Relative movements between particles may include sliding, rolling, elastic deformation or crushing. If the shear force continues, the mixture will deform to a point where the only way for further deformation to occur is either by breaking the aggregates or to cause aggregates to roll or slide *over* one another. Sliding aggregates over one another results in an increase in mixture volume which is called dilation.

7.4 Aggregate Resistance to Degradation

In addition to the aggregate characteristics which control mixture shear strength, aggregates must also be durable such to resist degradation. There are a multitude of variables which affect aggregate degradation. Many different types of actions or forces may cause aggregate particles to break-down. In general, it is perceived that tougher aggregates are more resistant to degradation. However, the nature of the forces causing aggregate degradation control the type and amount of break-down which may occur. For

example, an aggregate that is very resistant to impact may not necessarily be resistant to abrasive wear, and vice versa.

7.4.1 Causes of Aggregate Degradation

Aggregate handling At the aggregate production facility and at the asphalt plant, the handling actions of heavy equipment can crush and abrade aggregates. Each time the aggregate is moved (stockpiling, loading, transporting, and unloading) the aggregate may degrade. As an example, aggregates mined in south Florida, transported by rail to terminals in north Florida, and then hauled to asphalt plants have been known to increase five to ten percent for the material passing the primary sieves. In these operations, the actions causing degradation are generally abrasive or low velocity impact forces upon loose (uncompacted) stockpiles of aggregates of a uniform size.

Asphalt mixture production Aggregate degradation also may occur in the drum/dryer during asphalt mixture production. One contractor in Michigan [49] stated that during the production of an SMA, break-down of the stone resulted in an increase of five to eight percent in the No.4 (4.75 mm) to No.8 (2.36 mm) fraction. In Florida, similar experiences are reported to occur during the production of open-graded friction course mixtures. One contractor found that breakdown was usually between two to three percent passing the No.4 sieve at one plant, and four to five percent at another plant.

In the drum, the combined aggregate components are picked up and veiled through the burner's combustion gasses by a series of flights mounted to the inside of the rotating drum. Drum diameters typically range between five and ten feet. Mechanisms of

degradation in the drum include the abrasive actions of sliding down the side of the drum and free-fall impact when the aggregates drop off the flights.

Another form of aggregate degradation that may occur in the drum is thermal shock. As the aggregate particles pass through burner gasses as hot as 1400°F, the rapid differential expansion of minerals and/or expansion of internal moisture into steam may fracture or disintegrate some aggregate particles.

In batch type plants, degradation can occur during the mixing operation in the pugmill. Abrasion by the paddles, grinding and crushing between the paddle tips and sides of the pugmill, and abrasion of aggregates on aggregates cause break-down of particles.

Placement and compaction During placement and compaction of the mixture, aggregates are subjected to forces from the paving machine screed and rollers which may cause particles to fracture. Modern paving machines have vibratory screeds or screeds equipped with tamping bars which provide up to 90 percent of the mat density. The dynamic forces applied by these screeds could result in crushing or breaking of aggregate particles.

Likewise, aggregate particles may break under the compaction forces applied by either static or vibratory steel wheel rollers. For example, the Florida DOT restricts rollers for open-graded friction courses to static rollers with gross weights less than 135 pli (pounds per lineal inch of drum width) to minimize crushing of aggregates [50].

Mention of crushed surface aggregates due to paving and or compaction occurs occasionally in the literature, particularly with gap-graded type mixtures. However, it is rarely quantified in terms of change in gradation.

Traffic and environment After construction, aggregates continue to be subjected to environmental and load related actions which may cause degradation. Aggregates on the surface of the pavement are subjected to abrasive wear by tires. Studded tires and tire chains used to provide traction on snow and ice covered pavements are particularly abrasive to pavement surfaces.

Freeze-thaw cycles and wet-dry cycles can cause some aggregates to break-down. This type of degradation is more prevalent in absorptive aggregates with pore structures that can be permeated by water. Since most asphalt pavements are essentially impervious, cyclic freeze-thaw and wet-dry actions are probably active only at or near the pavement surface where water can penetrate.

Repeated wheel loads applied at the pavement surface are distributed through the pavement structure. The highest shear and compressive stresses occur at or near the pavement surface beneath the load. In the asphalt layers, the compressive and shear stresses are carried through point to point contacts between aggregates. High contact stresses between particles may cause aggregate fracturing and or chipping of sharp edges.

Results from an early Missouri SMA project [51,52] indicate that within one year after construction, the aggregate had degraded from five to seven percent between the 3/8" sieve and the No.16 (1.18 mm) sieve. Data from a Virginia SMA investigation [39] shows the gradation shifted about five percent on the No.4 sieve in less than one year of traffic.

7.4.2 Effects of Degradation

The obvious result of any degradation is that the gradation becomes finer. How much finer and on what sieves are the important questions. At what time during the sequence of production, placement and service, the degradation occurs is also important to the way it affects performance.

Aggregates degraded prior to or during mixture production will be coated with asphalt, but may significantly alter the properties of the finished mixture. A finer gradation will increase the surface area of the aggregate blend and reduce the asphalt film thickness which could diminish the durability of the mixture. A shift toward a finer gradation will also affect the VMA of the mixture as shown in Figure 41. For gradations above the maximum density line, a shift toward a finer gradation will generally increase VMA. However, if a lot of fines (<75μm particles) are generated VMA can be reduced. For gradations below the maximum density line, degradation will always result in lower VMA. For most types of mixtures, a decrease of the VMA is detrimental due to the corresponding loss of air voids.

However, degradation during handling and production can be adjusted for by starting with a blend of components that is coarser than the target for the finished mixture and/or by wasting fines from the dust collection system. To do this, it is necessary to know where and how much the gradation will shift for the particular mixture and the production conditions. This practice is common in the production of asphalt mixtures in Florida and is likely practiced elsewhere.

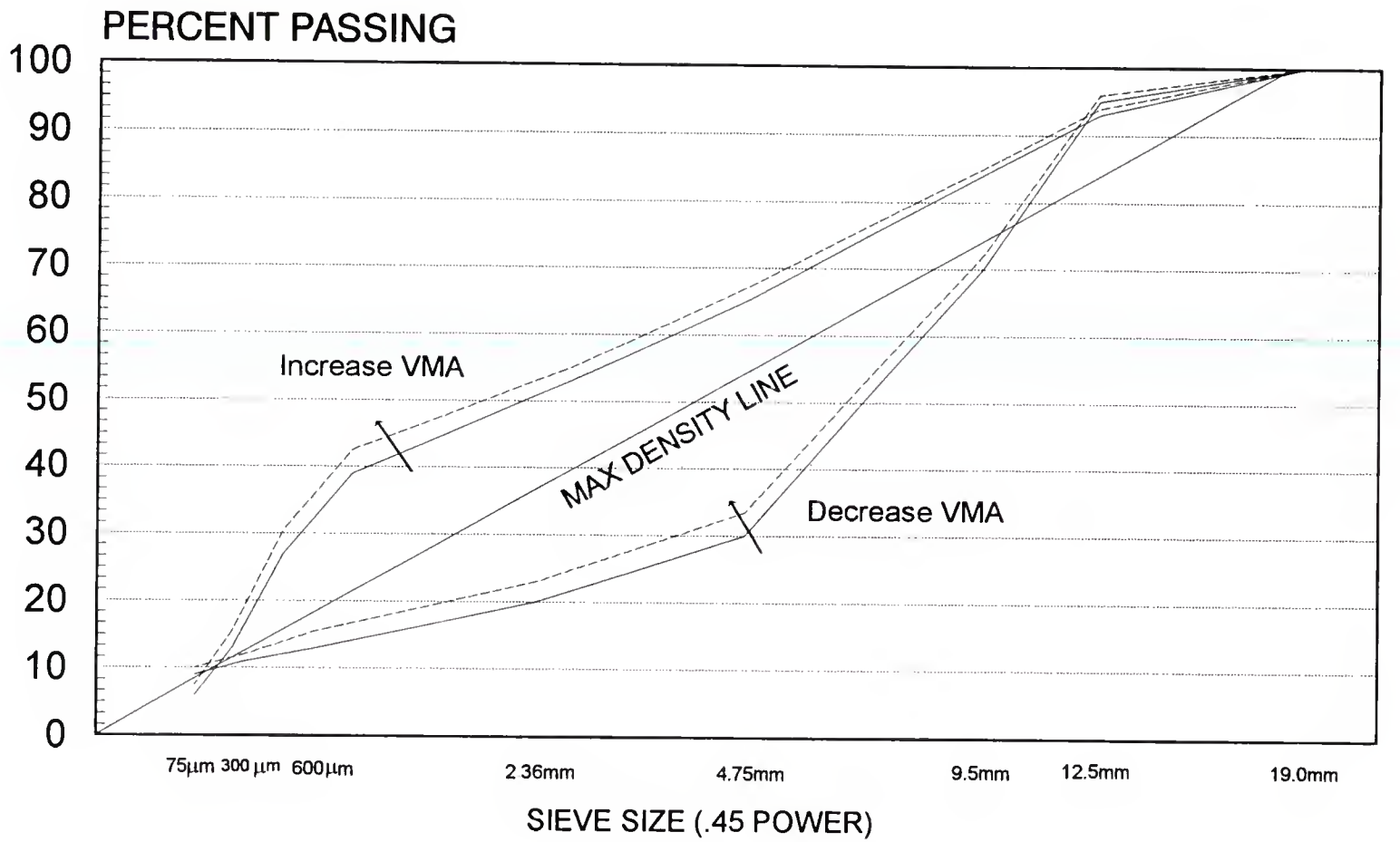

Figure 41. Illustration of VMA Change Due to Aggregate Degradation

Degradation which occurs after mixing will leave particles partially uncoated and more open to penetration by water. Broken aggregates on the pavement surface can cause ravelling and or result in a loss of skid resistance. Degradation of aggregates below the pavement surface could be detrimental to shear strength and resistance to cracking.

7.5 Tests for Aggregates

Many of the important aggregate characteristics can be measured or indirectly evaluated with standardized tests. However, some of these tests have serious limitations and may not be representative of conditions which exist in the field. There is a now a national consensus among asphalt materials engineers that better tests need to be developed for assessing some aggregate characteristics. The following discussion identifies the current methods used to evaluate particular aggregate characteristics.

7.5.1 Gradation

The distribution of particle sizes in an aggregate component or a blend of aggregates is determined by sieve analysis (AASHTO T 27, ASTM C 136). An aggregate sample is separated into different size fractions by allowing the sample to pass through a nest of wire-cloth sieves arranged so that the sieve with the largest openings is on top and progressively finer sieves are below. A pan is placed on the bottom of the stack of sieves to catch any particles that pass through the smallest sieve. The aggregate sample poured into the stack of sieves is shaken either by hand or using a mechanical

shaker until further shaking does not result in any additional particles passing through the sieves. The weight of aggregate retained on each sieve and in the pan is determined and then converted to percentage retained or cumulative passing

Often, a washed gradation (AASHTO T11, ASTM C 117) is necessary to get an accurate measure of the material passing the 75μm sieve. In this test, the aggregate sample is placed in pan of water and agitated slightly to separate the fine dust coatings on the aggregate particles. The water is then decanted over a No. 200 sieve so that the very fine dust coatings can pass through and the particles larger than 75 μm can be returned to the sample. A dispersing agent, to aid in separating the fines, is allowed in the ASTM procedure and an in the alternate procedure AASHTO. Following the washing, the sample is dried and sieved using the dry sieving procedures given above. The weight of fines lost during the washing is added to the weight retained in the pan for computation of the gradation.

7.5.2 Shape

No method is available which quantifies or measures overall particle shape. Describing particle shapes using subjective terms such as rounded, sub-angular, cubical, elongated, discoid, etc. is meaningful to mix design engineers, but is not applicable to specifications. Two methods that are often used to quantify the percentage of particles that have general types of shapes are Flat and Elongated Particles, and Percent Crushed Faces. Flat and Elongated Particles (ASTM D 4791) is a method by which a sample of

coarse aggregate particles are checked individually to determine if the primary particle dimensions exceed a specified ratio using a simple proportional caliper.

Although a standardized procedure for measuring the percentage of fractured faces in an aggregate is yet to be established at the national level, the requirement for a high percentage of fractured faces (or percent crushed particles) is common in specifications. The percentage of fractured faces is typically determined by manually sorting through a representative sample of coarse aggregate and counting or weighing the particles with one or two fractured faces.

7.5.3 Surface Texture

Surface texture is also a difficult characteristic to measure or quantify. The particle index test (ASTM D 3398) can be used to indirectly assess surface texture and particle shape of coarse aggregates. In the particle index test, aggregates separated into individual size fractions are tamped into a cylindrical steel mold in three equal layers with two different compactive efforts. Mold dimensions and tamping rod weights are specified for different aggregate sizes. The first compactive effort applied is 10 drops of the tamping rod from two inches above the layer. Fifty drops from two inches is used for the second compactive effort. From the weight of the compacted sample and the bulk specific gravity of the aggregate, the percentage of voids is determined for each compacted

sample. The particle index is then calculated using the following equation:

$$I_a = 1.25V_{10} - 0.25V_{50} - 32 \quad (11)$$

where:

I_a = Particle index;
V_{10} = percent voids in the sample compacted with ten tamps per layer;
V_{50} = percent voids in the sample compacted with fifty tamps per layer.

The particle index for a complete gradation can be mathematically determined by multiplying the particle indices of each fraction by the percentage of the gradation represented by that fraction and summing the products. Particle indices of smooth, rounded aggregates are low, typically less than ten; angular, rough-textured aggregates usually have particle indices of about 15.

A similar test was developed by the National Aggregate Association for fine aggregates. Known as the "NAA fine aggregate test" or the "uncompacted voids test", this test consists of allowing the fine aggregate to fall loosely from a funnel into a small standardized cylinder. The aggregate sample is dried and sieved to meet a specified gradation prior to the test. As with the particle index test, the void content of the sample is determined from the mass of aggregate filling the cylinder and the bulk specific gravity of the aggregate. Fine aggregates consisting of angular, rough particles will supposedly have higher void contents.

7.5.4 Resistance to Degradation

A variety of tests are available which indicate the resistance of an aggregate to breakdown to some type of action. The most popular test in the U.S. for evaluating

aggregate toughness is the L.A. Abrasion test. The L.A. Abrasion test (AASHTO T-96, ASTM C 131) consists of tumbling a 5000 gram sample of graded aggregate in steel drum with 6 to 12 steel balls for 500 revolutions. A steel shelf on the inside of the drum lifts and drops the aggregate and steel balls about 27 inches during each revolution. The aggregate sample is then sieved over a No. 12 (1.70 mm) sieve, and the percentage of the total aggregate passing is expressed as "the loss" or more commonly referred to as the L.A. Abrasion value.

Aggregate Durability Index (AASHTO T 210) is another degradation test which is intended to indicate the relative resistance of an aggregate to generate detrimental clay-like fines when subjected to agitation in the presence of water. The Durability Index test for coarse aggregate involves washing and agitating for two minutes a prepared gradation, then the minus No.4 material is discarded and the washed sample is sieved to meet the final test grading. This sample is placed in a specified vessel with distilled water and agitated on a sieve shaker for 10 minutes. The wash water and minus No. 200 material are then collected and mixed with a solution of calcium chloride in a plastic cylinder. Following a sedimentation time of 20 minutes, the height of the sediment column is measured. The Durability Index is then calculated using a given equation from the height of the sediment.

Other tests which indicate aggregate resistance to degradation by mechanical actions are used in other countries. In the United Kingdom, the Aggregate Impact Value test and the Aggregate Crushing Value test are used to evaluate aggregate quality. These tests are also apparently used by Sweden [9] to specify aggregates for SMA mixtures.

The Aggregate Impact Value is determined by dropping a 30 pound hammer from 15 inches onto a prepared -½ +⅜ inch aggregate sample in a cylindrical steel mold. The sample is subjected to 15 blows of the hammer then resieved over the British Standard 2.40 mm sieve. The percentage of the sample which passes the 2.40 mm sieve is the Aggregate Impact Value. In the Aggregate Crushing Value test, the aggregate sample is prepared the same as in the impact test, but is then subjected to a continuous load in a compression machine. The load is applied gradually up to 90,000 pounds over a period of ten minutes. The sample is then re-sieved over a 2.40 mm sieve and the percentage of the sample passing is the Aggregate Crushing Value.

The micro-Deval test developed in France has been used by the Ontario Ministry of Transportation to evaluate the durability of construction aggregate [7]. The micro-Deval test is performed on an aggregate sample consisting of 250 grams of -¾ +½ inch material and 250 grams of -½ +⅜ inch material. The sample is soaked for 24 hours then placed in a jar mill with distilled water and eleven pounds of ⅜ inch diameter steel balls. The jar mill is rotated at 100 rpm for 2 hours then the sample is dried and sieved over a No. 16 (1.18 mm). The loss is the weight percentage of the sample passing the No. 16 sieve.

Clay Lumps and Friable Particles (AASHTO T-112, ASTM C 142) is a test to detect the presence of soft deleterious particles that easily crumble when saturated. The test sample is prepared by first washing the aggregate using the washed gradation procedure described in Section 4.5.1, then separating the aggregate into individual sizes. The test samples are then placed in a container in a thin layer and covered with distilled

water for 24 hours. Following the soak period, the individual particles are rolled between the thumb and forefinger to attempt to crumble the particles. The samples are then washed over a smaller sieve and the percentage of the sample passing the sieve is calculated as the percent of clay lumps and friable particles.

The Sulfate Soundness test (AASHTO T 104 , ASTM C 88) is used to evaluate the resistance of an aggregate to weathering. The test is intended to simulate the degradation which results from the expansion of ice crystals in the pores of an aggregate as well as other environmental effects. The sulfate soundness tests consists of cycling a prepared sample of coarse aggregate in a solution of sodium or magnesium sulfate for approximately 18 hours, then drying the sample in an oven at 230°F. Following a specified number of cycles, the sample is washed to remove the sulfate salt crystals and then sieved. The loss on each sieve is determined and the weighted average loss for the entire sample is computed.

7.5.5 Cleanliness

A number of tests are available which provide a measure of aggregate cleanliness. The washed gradation test described in Section 4.5.1 is one test that can be used to indicate the presence of undesirable quantities of clay or other dust coatings on coarse aggregates. The procedure for detecting clay lumps and friable particles described in Section 4.5.4 can also be used to screen out aggregates that contain materials that may form deleterious coatings.

The Sand Equivalent (AASHTO T-176, ASTM D 2419) is a procedure used to indicate the amount of clay size material in a sample of fine aggregate. The Sand Equivalent tests consists of mixing the sample of fine aggregate with a flocculating solution in a graduated cylinder. The sample is thoroughly agitated and flushed with additional flocculating solution to force the fines into suspension. The cylinder then is allowed to stand undisturbed for a period of sedimentation. Following the period of sedimentation, the heights of the fines and sand are observed. The Sand Equivalent is defined as the ratio of the sand height to the height of fines.

7.5.6 Resistance to Polishing

Resistance to polishing is the ability of an aggregate to withstand traffic abrasion without becoming smooth. It is an essential aggregate characteristic for asphalt mixtures used as the surface layer of pavements. In practice, experience with particular types of aggregates has been used to identify which aggregates are resistant to polishing. For instance, limestones are generally known to polish and are usually prohibited from surface mixtures. However, some limestone aggregates contain sand-size quartz crystals that are continually exposed as the softer calcite grains are worn away. The acid insoluble test (ASTM D 3042) has been used to identify such limestones. The acid insoluble test consists of reacting a 500 gram sample of minus ⅜ inch, plus No. 4 sieve carbonate aggregate with 6 *N* hydrochloric acid (HCl). When the reaction is completed, the acid is diluted then the sample is rinsed over a No. 200 sieve. The material remaining after rinsing is the plus No. 200 insoluble residue.

Some highway agencies have used the British Polishing Wheel (AASHTO T-279, ASTM D 3319) to evaluate polishing resistance of aggregates. This accelerated laboratory polishing test utilizes minus ½, plus ⅜ inch aggregates bonded in small curved panels with cement mortar or polyester resin. Fourteen panels are attached to a sixteen inch diameter wheel and the wheel is then rotated at a speed of 320 rpm against a standard rubber tire for 10 hours. A standard abrasive and water are fed between the tire and wheel throughout this time. Following the polishing test, the samples are individually tested with the British Portable Pendulum Tester (AASHTO T-278, ASTM E 303). This device consists of a small weighted pendulum with a rubber slider that swings to contact the polished sample. The energy dissipated by the frictional contact between the swinging slider and the aggregate sample is indicated by the height the slider reaches at the end of the swing. The height is measured on a scale which is graduated in British Pendulum Numbers.

7.5.7 Adhesion with Asphalt

Adhesion between the asphalt film and the aggregate surface is known to be affected by many aggregate characteristics such as mineralogy, surface texture, cleanliness, and absorption. However, adhesion of the asphalt coating to the aggregate, particularly in situations involving water or moisture vapor, is also complicated by many other factors. For this reason, an evaluation of asphalt-aggregate adhesion is probably best evaluated as part of the mix design process, rather than on individual aggregate components. The most

popular test for evaluating the resistance of asphalt mixtures to moisture induced damage is AASHTO T 283, commonly known as the wet/dry indirect tensile strength test.

7.6 Aggregate Specifications

Specifications limits for traditional physical properties of coarse aggregates used in asphalt mixtures are summarized in Table 21. It can be seen that the requirements differ widely among the state highway agencies. For example, specification limits on L.A. Abrasion range from 30 percent maximum loss to 50 percent maximum loss. Requirements for the other properties vary as well. Some states do not have a specification on certain properties. The FDOT no longer has a Sulfate Soundness requirement for aggregates produced for asphalt mixtures because it is thought thatthis test is not representative of the no freeze environment for most of this state. It is also apparent that the recommended specifications for SMA aggregates are more stringent.

Table 21. Summary of Coarse Aggregate Specifications

	AASHTO Class A	AASHTO Class B	AASHTO Class C	Range of Spec. Limits from States	FDOT	SMA	Method
L.A. Abrasion max. % loss	40	45	50	30 - 50	45	30	AASHTO T 96
Sulfate Soundness max. % loss	12	12	12	N.S., 9-15, (M) 10-12	N.S.	15	AASHTO T 104
Fractured Faces min. %/ faces	75/2	75/2	75/2	40-100/1 90/2 85/3 N.S.	85/3	100/1 90/2	VARIES
Flat & Elongated max. percent with length/thickness> 5:1	15	15	15	5-25, N.S.	N.S.	5	ASTM D 4791
Absorption max. %	N.S.	N.S.	N.S.	1.7 - 5, N.S.	N.S.	2	AASHTO T 85

N.S. - not specified

The specific guideline specifications for SMA aggregates, as recommended by the Technical Working Group [20], are as follows:

Aggregate Requirements:

Coarse Aggregate:

General Requirements- Coarse aggregate shall be crushed, non-absorptive stone and unless otherwise stipulated, shall conform to the following requirements of AASHTO M 283 for class A aggregates:

1. Los Angeles Abrasion, AASHTO T 96	*30% max.*
2. Flat and Elongated Particles, ASTM D 4791	
3 to 1	*20% max.*
5 to 1	*5% max.*
3. Sodium Sulfate Soundness Loss, AASHTO T 104	
5 cycles	*15% max.*
4. Particles retained on the No.4 sieve shall have at least:	
one fractured face	*100% min.*
two fractured faces	*90% min.*
5. Absorption, AASHTO T 85	*2% max.*
6. Coarse and fine Durability index, AASHTO T 210	*40% min.*
7. Relatively pure carbonate aggregates shall not be used	

Fine Aggregate:

General Requirements: Fine aggregates shall consist of a blend of 100% crushed manufactured sand. It shall conform to the following quality requirements of AASHTO M 29:

1. Sodium Sulfate Soundness Loss, AASHTO T 104	
5 cycles	*15% max.*
2. Liquid Limit, AASHTO T89	*25% max.*

These recommended specifications are intended to be restrictive to limit SMA aggregates to only high quality materials. This restrictive approach was based partly on the advice of European experts who developed or had extensive practice with SMA mixtures. Members of the SMA Technical Working Group also recognized from their own experiences the need to use aggregates with certain characteristics which would affect the performance of SMA mixtures. More specifically, it was desired to specify the aggregate characteristics or properties which would have positive effects on mixture shear strength since it is intuitively recognized that the stone-on-stone contact of SMA mixtures relies more heavily on the coarse aggregate for deformation resistance. It is also important for SMA aggregates to be very resistant to degradation during mixture production to maintain a good VMA and a gradation which provides good stone-on-stone contact, and resistant to degradation during placement and service to avoid potential problems with ravelling, cracking and loss of shear strength. The potential for aggregate degradation in the pavement is greater for SMA mixtures than for dense-graded mixtures due to the gap gradation which produces the stone-on-stone contact, but which also reduces the number of contact points between aggregates. This, in turn, results in higher contact stresses between particles which may cause some aggregates to fracture.

However, the difficult task for the TWG was to select aggregate properties and their limits which were related to shear strength and resistance to degradation. For shear strength, the gradation was set to force good stone-on-stone contact, and good particle shapes were defined by limits on the percentage crushed faces and the percentage of flat and elongated particles. For degradation resistance, conservative limits were set for L.A.

abrasion, Sulfate Soundness, and Durability Index. The limitation on absorption was apparently set to assure that the minimum asphalt content specified as part of the mix design would provide an adequate effective asphalt volume for mixture durability. The prohibition of carbonate materials for use as coarse aggregate was to avoid the problem of polishing and loss of skid resistance.

The L.A. abrasion, sulfate soundness and Durability Index tests were selected for evaluating degradation resistance because these are the only tests available for that purpose. However, the applicability of these tests and the suggested criteria should be carefully considered during aggregate selection. These tests may overemphasize some of the less important aspects of aggregate durability and neglect to evaluate the important situations which are critical to the aggregates performance in an SMA mixture. The Aggregate Handbook [45, p. 3-45] offers a statement of caution regarding the use of the L.A. abrasion test.

> "Certain rock types appear... to be superior to other types based upon test results from the widely specified Los angeles Degradation Test; this, however, is not necessarily true. The Significance and Use sections of ASTM Test Methods C 131 and C 535 state: "Specification limits based on these tests should be assigned with extreme care in consideration of available aggregate types and their performance history in specific end uses."

Likewise, Sulfate Soundness and Durability Index have not been shown to be related to aggregate degradation in asphalt mixtures. In fact, the Durability Index test was developed in California primarily to evaluate coarse aggregates for use in aggregate base, permeable backfill material, and riprap rock.

Two important aggregate characteristics that are not evaluated in the current specifications are surface texture and crushing strength. Aggregate surface texture affects the frictional resistance between particles. The crushing strength of an aggregate will affect shear strength and the resistance to degradation. These characteristics were evaluated for some of the study materials. Surface textures were evaluated indirectly using the Particle Index test. Crushing strengths of a few aggregates were measured by individually testing a sample of aggregates in a compression machine. Both characteristics also were assessed by compacting the dry aggregates in the Gyratory Testing Machine.

7.7 Test Procedures

7.7.1 Particle Index

The particle index test (ASTM D 3398), described in section 7.5.3, was performed on the 9.5 mm to 4.75 mm (⅜" to No.4) size fractions of thirteen of the study aggregates. The finite supply of some materials limited the number of tests that could be performed with some mixtures. Only the 9.5 mm to 4.75 mm fraction was tested because this is the size range that dominates the SMA gradation and creates most of the stone-on-stone contact.

7.7.2 Crushing Strength

The purpose of this test was to determine the compressive strength of aggregate particles. Individual aggregate particles were randomly taken from a sample of minus ½ inch, plus ⅜ inch aggregate. Each particle was placed on a hardened steel plate in a Tinius Olsen Compression/Tension machine. A hardened steel plate fixed to the machine

crosshead was lowered to contact the particle, then the machine was set to travel at a rate of 0.5 inches/minute until the particle fractured. Particle fracture was defined as when all of the particle fragments passed through a standard ⅜ inch sieve. The maximum compressive load carried by the particle was recorded. Thirty aggregate particles were tested for each aggregate source.

7.7.3 GTM Aggregate Strength and Degradation

Background Evaluation of aggregate degradation using the GTM was first researched by Moavenzadeh and Goetz in 1963 [53]. Their study utilized a GTM equipped with a fixed roller. Three aggregates with L.A. abrasion values of 33, 27.5, and 24.9 (Grading C) were tested in three gradations ranging from an open grading to a well graded blend. Aggregate samples were tested dry and mixed with asphalt at a normal compaction temperature. The compactive effort was varied by adjusting the setting for the vertical pressure and testing over a wide range of gyrations. Degradation was analyzed by calculation of the percent change in surface area for the sample gradation from before to after the test.

This work demonstrated many of the expected trends of aggregate degradation due to wear and breakage in the GTM. Aggregates with lower L.A. abrasion loss also had less degradation in the GTM. However, for soft materials, the L.A. abrasion test was much more severe than the GTM in producing degradation of the aggregates. In terms of surface area, open-graded blends had much more degradation than well-graded blends. This was because the open-graded blends started with no fines, and therefore, the

generation of any fines caused a dramatic increase in surface area. Also, as expected, higher vertical pressures and more gyrations increased degradation, but both factors had decay-type effects. In other words, as the vertical pressure or the number of gyrations increased the change in degradation diminished. Results also showed that mixing the aggregates with asphalt reduced the amount of degradation. This is attributed to the lubrication affect of the asphalt.

Comparison of the gradation changes reported by Moavenzadeh and Goetz with typical degradation which occurs during field production, placement and service of asphalt-aggregate mixtures as reported in the literature, indicates that the lowest compactive effort used in their study is most representative of field conditions.

Procedure Aggregate samples were prepared by combining the individual aggregate components to meet the desired gradation of the finished mixture (the JMF) in the same way samples were prepared for mixture tests such as the Marshall test. Total aggregate weight was adjusted based on specific gravity to yield sample heights that ranged between 2.5 and 3.0 inches during the test.

The prepared samples were then carefully placed in a 4 inch diameter mold to avoid segregation. To minimize the loss of fines, a small o-ring was placed at the bottom of the mold along the base plate. The sample and mold were then loaded into the GTM and compacted to 25 gyrations.

Initial settings for the GTM model 6B-4C were 9 psi air roller pressure (unloaded), and a 3 degree angle of gyration. The ram pressure was maintained at 100 psi throughout the test. The roller carriage rotating around the flange of the mold chuck creates a

moment which results in a shear strain imparted to the sample. The shear strain and the ram pressure cause the aggregate sample to consolidate into a dense arrangement. As aggregate particles become tightly interlocked, the sample resists the shear strain which causes the air roller pressure to increase and the angle of gyration to decrease.

Sample heights and air roller pressures taken every 5 gyrations were used to compute two of the analysis parameters: dry voids in mineral aggregate (Dry VMA) and gyratory shear strength (τG) using the following equations.

$$Dry\ VMA = 100\left(\frac{G_{sb} - \frac{M_s}{h}}{G_{sb}}\right) \quad (12)$$

where:

G_{sb} = Bulk specific gravity of the combined aggregate
M_s = mass of the sample, grams
h = height of the sample, inches

$$\tau G = \frac{7.216\ ARP}{h} \quad (13)$$

where:

ARP = air roller pressure, psi

Following the test, the samples were resieved to determine the amount of degradation. Three parameters were used to evaluate degradation: 1. the average shift in the percent passing of all sieves, 2. the change in percent passing the major size fraction (typically the 4.75 mm sieve), and 3. the change in calculated surface area of the

composite gradation. A single parameter was not felt to be adequate to quantify the magnitude and the distribution of the gradation change.

For the purpose of this study, surface areas were determined using a new set of surface area factors. The traditional surface area factors are applicable only for the standard set of sieves. Alternative sieves, such as used in this project, do not have factors. The new surface area factors are applicable to any sieves and were developed to be used with the percent retained on each sieve rather than percent passing. This is a much more logical approach since the surface area factors are an approximation of the surface area for individual size particles within each fraction.

Development of surface area factors The first step in the development of the new surface area factors was to determine a relationship between the percentage by weight retained on any sieve and the actual number of particles retained. This relationship can easily be established if it can be assumed that the representative particle dimension is equal to the average of the opening of the sieve on which it was retained and the next larger sieve. For example, aggregate particles passing the 4.75 mm sieve and retained on the 2.36 mm sieve would be assumed to have an representative particle dimension of (4.75+2.36)/2 = 3.56 mm. The representative particle dimension of each fraction is used to calculate the volume per particle and the surface area per particle. Two geometrically simple shapes wnich can be completely described with a single dimension are spheres and cubes. It was therefore assumed that half of the particles in each fraction could be represented by a sphere, the other half by a cube. The following equation is then used to determine the volume per particle.

$$V = \frac{1}{2}\left(d^3 + \frac{\pi d^3}{6}\right) = d^3(0.7618) \quad \textbf{(14)}$$

where:

V = volume per particle for the given fraction
d = the representative particle dimension for the given fraction.

Now, for illustrative purposes, consider an aggregate sample with a total weight of 100 grams. Consequently, the percentage retained on each sieve is equal to the weight retained. By knowing the bulk specific gravity of the aggregate, the volume of aggregate on each sieve can be easily calculated. The number of particles retained on each fraction is therefore equal to the volume of aggregate on each sieve divided by the volume per particle as determined from equation 14. The equation to calculate the number of particles retained on any sieve is:

$$N = \frac{\frac{\%ret}{G_{sb}}}{V} \quad \textbf{(15)}$$

Next, the number of particles on each sieve is multiplied by the average surface area per particle for that size fraction. Average surface area per particle is calculated using equation 16. This equation also assumes that half of the particles are represented by a sphere and the other half by a cube.

$$A = \frac{1}{2}\left(\pi d^2 + 6d^2\right) = d^2(4.5708) \quad \textbf{(16)}$$

Surface areas for each size fraction are therefore the product of the number of particles on that sieve and the area per particle. The surface area of the entire gradation is then the sum of the surface areas for each size fraction. Using this technique, the surface areas for the standard and alternate sieves were determined and are shown in Table 23. For simplicity, these factors will be referred to as the "Percent-Retained, Equidimensional-Particles" or PREP surface area factors.

Table 23. New Surface Area Factors for the Standard and Alternate Sieves

Standard Sieves					Alternate Sieves				
Sieve	d (cm)	V (cm^3)	A (cm^2)	SAF[1] (cm^2/g)	Sieve	d (cm)	V (cm^3)	A (cm^2)	SAF[1] (cm^2/g)
1/2"	1.575	2.976	11.338	1.4	1/2"	1.575	2.976	11.338	1.4
3/8"	1.100	1.014	5.531	2.1	3/8"	1.100	1.014	5.531	2.1
No.4	0.713	0.276	2.324	3.2	No.4	0.713	0.276	2.324	3.2
No.8	0.356	0.0344	0.579	6.4	No.10	0.338	0.0294	0.522	6.7
No.16	0.177	4.2E-3	0.143	12.8	No.40	0.121	1.4E-3	6.7E-2	18.7
No.30	0.089	5.4E-4	3.6E-2	25.4	No.80	0.030	2.1E-5	4.1E-3	74.7
No.50	0.045	6.9E-5	9.3E-3	50.3	No.200	0.013	1.7E-6	7.7E-4	176.9
No.100	0.023	9.3E-6	2.4E-3	100.6	- 200	0.005	9.5E-8	1.1E-4	452.8
No.200	0.011	1.0E-6	5.5E-4	200.4	[1]Surface Area Factors based on Aggregate Specific Gravity = 2.65				
- 200	0.005	9.5E-8	1.1E-4	452.8					

Calibration of surface area factors The PREP surface areas factors were compared to the traditional percent passing factors and with experimental results from Barksdale et al. [54]. To make a direct comparison with the traditional percent passing surface area factors, they had to be algebraically converted to percent passing factors. Table 24 shows the traditional factors in terms of percent passing and percent retained. Also shown are

the PREP surface area factors. The differences column shows that the traditional factors are consistently between 18 and 22 percent greater than the PREP factors.

Table 24. Comparison of Traditional and PREP Surface Area Factors

Sieve	Traditional Factors			PREP Factors (cm^2/g)	Percent Difference
	% Passing (ft^2/lb)	% Retained (ft^2/lb)	(cm^2/g)		
Max Size	2				
No.4	2	2	4.1	3.2	22
No.8	4	4	8.2	6.4	22
No.16	8	8	16.4	12.8	22
No.30	14	16	32.7	25.4	22
No.50	30	30	61.4	50.3	18
No.100	60	60	122.8	100.6	18
No.200	160	120	245.5	200.4	18
Pan		280	572.9	452.8	21

Barksdale et al. [54] evaluated 21 aggregate sources by separating the gradations into four size fractions and calculating the surface area of each fraction using a three-dimensional tetrakaidekahedron (TKH) model for particle shape. They reported that this model gave reasonably good results compared to qualitative stereography. The surface area data of the 21 aggregate sources are summarized by the statistics in Table 25. The PREP surface areas for each fraction is also given in the table. For the top two aggregate particle size ranges which were narrowly defined, the differences between the Barksdale et al. data and the PREP surface areas are consistent with the differences shown between the traditional surface area factors and the PREP factors. However, for the bottom two

ranges shown in the table, which represent relatively large distributions of particle sizes, the differences are substantial. The reason for the large differences observed for the fine materials is likely due to the significant mica content of most of the aggregates used in the Barksdale et al. study. The equidimensional particle assumption of the PREP factors is not representative of the sheet-like mica particles and results in a gross under estimation of their surface area.

Table 25. Comparison of New Factors with Experimental Data

Particle Size Range	Barksdale et al. Data		PREP Calculations	Percent Difference
	Avg. Surface Area (cm^2/100 g)	Std. Dev. (cm^2/100 g)	Surface Area (cm^2/100 g)	
½" to ⅜"	245	17	205	16
No.4 to No.8	794	108	637	20
No.8 to No.120	13,527	3537	5307	61
- No. 120	1,679,301	419,148	45,284	97

Based on the differences observed between the PREP factors and the traditional surface area factors which were partly verified by experimental results, the PREP factors were adjusted by increasing the factors by 21 percent. This adjustment seems reasonable to account for particle surface irregularities, thin particles, etc. which result in larger surface areas.

CHAPTER 8
EVALUATION OF SMA AGGREGATE PROPERTIES

8.1 Traditional Aggregate Properties

The traditional physical properties for the study aggregates are shown in Table 26. These are results reported in the literature, and are not from tests performed as part of this research. For many of the aggregates from other states, the data is incomplete. For the Florida aggregates, including the limestone from Shelby County, Alabama, the results were obtained from the FDOT's aggregate control database in August, 1992, when the samples for this research were taken.

Table 26. Traditional Coarse Aggregate Properties

Mix I.D.	GA1	GA2	GA3	GA4	WI1	WI2	WI4	MD 1	TX1	VA1	FL1	FL2	FL3	FL4	FL5	FL6
LA Abrasion (% loss)	35	35	20	39[1]	25	25	26	11	25	16	31	36	39	47	23	44
Crushed Faces (% 1F)	100	100	100	100	100	100	93[2] 83[3]	100	100	100	100	100	100	100	100	100[2] 85[3]
Sulfate Soundness								0.3	8							
Flat & Elongated (% >5:1)	1	1	1	3			<5		0		0	0	0	0	3	0
Absorption (%)								0.6		0.5	3.0	2.3	2.7	5.1	1.0	0.4

[1] weighted average of coarse aggregates
[2] percent with one crushed face
[3] percent with two crushed faces

8.2 Particle Index

Particle Indices for the thirteen aggregates are shown in Table 27. The results do appear to provide an relative indication of particle shape and surface texture. The aggregates with the lowest particle indices are WI4 and FL6. These are the two river gravel aggregates which contain some rounded particle and smooth surfaces despite their being thoroughly crushed. FL2, a relatively soft limestone, which also contains some rounded particles and chalky surface coatings, also has a low particle index. Based on general visual evaluations, the aggregates with more cubical, angular shapes and good irregular textures tend to have higher particle indices. A statistical comparison of the particle indices is shown in Figure 42. This test has a very low coefficient of variation and is therefore capable of easily distinguishing differences among the study aggregates.

Table 27. Results of the Particle Index Test on the -3/8, +No.4 Aggregate Fractions

Mix I.D.	GA1	GA2	GA3	WI1	WI4	MD1	TX1	FL1	FL2	FL3	FL4	FL5	FL6
Particle Index	12.6 12.4	11.9 12.1	14.3 14.5	11.5 11.7	8.7 8.8	14.4 14.2	12.2 12.6	13.7 13.6	9.9 10.2	12.4 12.4	11.7 11.8	14.6 14.8	10.3 10.6

General Linear Models Procedure

Dependent Variable: Particle index

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	12	76.0229	6.3352	0.139	328.53	0.0001

$\alpha = 0.05$
R-Square = 0.997
C.V. = 1.135

Duncan Grouping

Means with the same letter are not significantly different

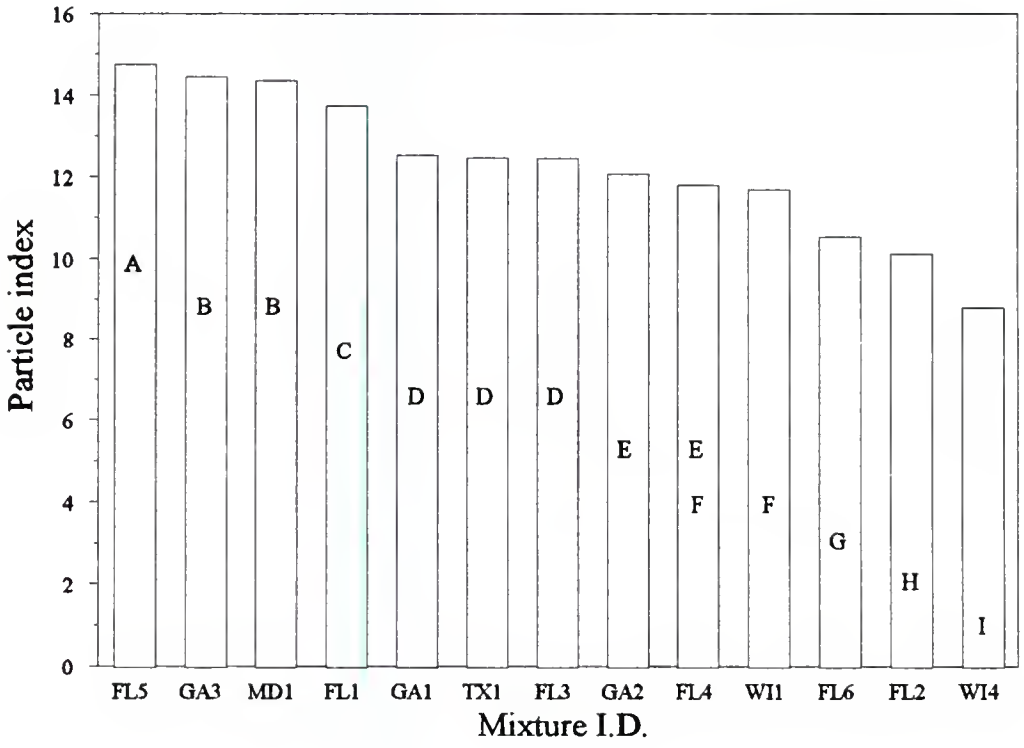

Figure 42. Comparison of Particle Index Test Results on the -⅜ +No.4 Fraction

8.3 Crushing Strength

Results of the crushing strength tests for five aggregate sources are shown in Table 27. It is evident from these statistics that each aggregate source has a wide distribution of particle strengths. This reflects the difficulty of determining the point at which to stop the test and record the load. For some particles, the point of fracture was not apparent until the load was released. In some cases, the particles crumbled when the load was removed which indicated that the initial point of fracture was not accurately observed. In other cases, corners or edges would break off, but the particle would not pass the sieve and therefore the particle was retested. Some variability may also be attributed to small differences in loading rate since this was manually set for each particle using a crude dial on the machine. Due to the large variability in results for these five sources, it was decided to discontinue the test.

Table 27. Results of Crushing Strength Tests

Mix I.D.	GA1, GA2	GA3	FL1	FL4	FL6
Rock Type	Granite	Granite	Limestone	Crushed Concrete	River Gravel
Average Crushing Strength (lbs)	113.5	162.1	77.0	97.8	160.2
Standard Deviation (lbs)	30.2	83.1	24.7	30.8	42.3
Coefficient of Variation (%)	26.6	51.3	32.1	31.5	26.4

However, despite the large variability, the results do show that aggregate particles from some sources are generally stronger than others in terms of crushing strength. It is

also apparent that crushing strength does not necessarily correspond to resistance to degradation as measured in the L.A. abrasion test. For example, the river gravel, FL6, which typically has an L.A. abrasion value in the mid to upper 40's, has an average crushing strength similar to the Ruby granite which has an abrasion value in of about 20, and is stronger than several other lower L.A. aggregates.. This illustrates the point that the L.A. abrasion test, which uses impact and abrasive forms of energy, may not properly indicate the strength of some aggregates to resist simple compressive forces which occur during pavement compaction and under traffic.

8.4 GTM Aggregate Strength and Degradation

Results of the GTM aggregate strength and degradation test are shown in Table 28. The first row below the Mix I.D. is the aggregate gyratory shear strength at 25 gyrations. This parameter was believed to be an indication of the internal friction of the aggregate blend. The internal frictional resistance will depend on the gradation, aggregate angularity, aggregate surface texture and aggregate strength. However, the test confounds these factors and makes the analysis of the different characteristics more complicated.

Statistical comparisons of the aggregate gyratory shear strengths are shown in Figure 43. It is evident that this parameter has low variability (low coefficient of variation) which enables a high degree of contrast to distinguish between a large number of Duncan groups.

Table 28. Results of GTM Degradation Tests

Mix I.D.	GA1	GA2	GA3	GA4	WI1	WI2	WI4	MD1	TX1	VA1	FL1	FL2	FL3	FL4	FL5	FL6
τG (psi)	69.5 68.8	73.1 73.2	65.6 68.2	69.9 71.2	64.9 65.6	69.7 66.9	58.4 57.5	73.9 74.2	61.7 63.5	68.4 67.6	67.0 63.6	60.0 59.7	56.2 57.2	69.3 69.3	73.6 72.6	72.6 70.6
Dry VMA (%)	22.5 23.2	26.4 26.4	25.5 26.5	22.4 22.1	25.7 26.5	23.3 23.5	27.8 27.4	27.5 27.5	27.1 26.4	25.8 26.7	23.8 23.2	23.9 22.7	24.9 25.3	24.1 24.2	24.9 24.5	24.2 23.0
GDI	2.8 2.3	1.7 1.7	1.5 1.7	1.9 2.2	1.5 1.6	1.7 1.7	0.7 0.6	1.5 1.5	2.3 2.3	0.7 0.7	2.0 2.0	2.4 2.5	2.3 2.5	1.9 2.1	1.6 1.7	1.1 1.1
Initial Surface Area	76.2	79.7	72.9	74.3	65.8	80.0	61.3	60.6	67.6	80.0	70.0	71.5	69.2	76.9	62.5	64.7
Final Surface Area	69.0 69.2	74.5 73.1	69.8 69.9	63.0 62.9	61.2 61.0	77.0 77.1	60.9 60.0	55.3 54.9	64.1 63.6	78.8 79.0	67.4 68.7	63.7 64.8	61.4 61.0	71.8 71.5	57.8 57.4	60.3 60.2
ΔSA ($cm^2/100g$)	7.2 7.0	5.2 6.6	3.1 3.0	11.3 11.4	4.6 4.8	3.0 2.9	0.4 1.3	5.3 5.7	3.5 4.0	1.3 1.0	2.6 1.3	7.8 6.7	7.8 8.2	5.1 5.4	4.7 5.1	4.4 4.5
ΔMS (%)	11.1 9.2	6.6 6.7	6.2 6.9	7.7 8.7	6.3 6.2	5.3 6.5	2.7 2.4	6.2 5.8	7.3 9.4	2.9 2.8	7.3 7.7	10.2 9.7	9.0 10.0	8.5 7.5	6.4 6.8	4.4 4.5

General Linear Models Procedure

Dependent Variable: Gyratory shear strength of aggregates

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	15	871.0672	58.0711	1.114	46.80	0.0001

$\alpha = 0.05$
R-Square = 0.978
C.V. = 1.663

Duncan Grouping

Means with the same letter are not significantly different

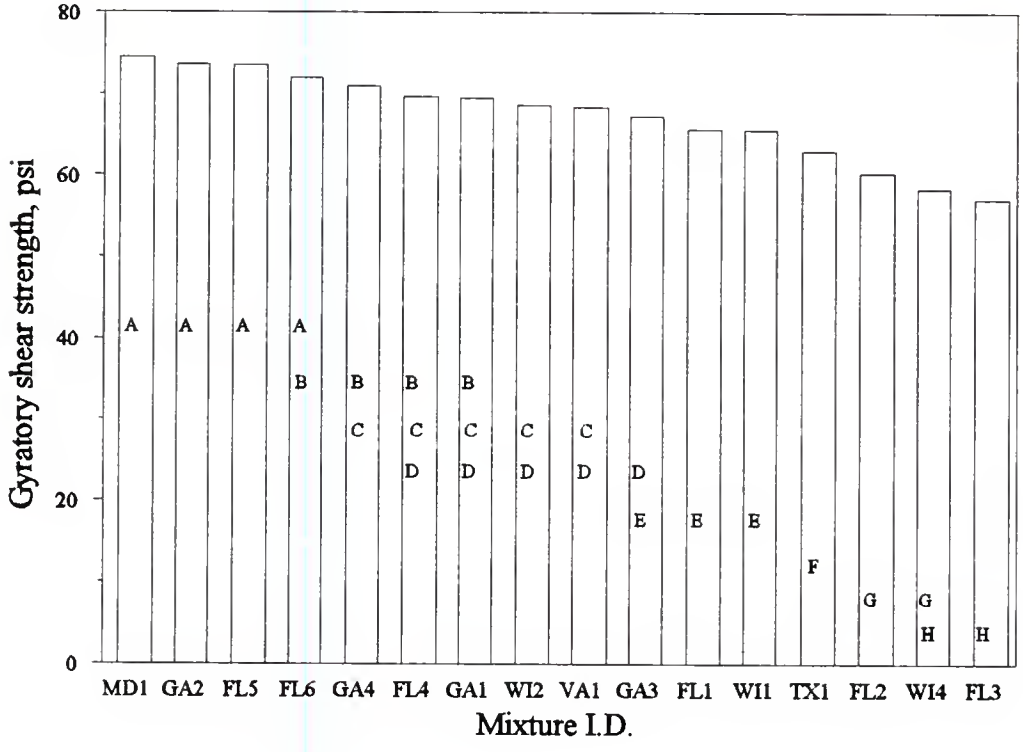

Figure 43. Comparison of Aggregate Shear Strengths

Analysis of the Florida aggregates is somewhat simplified since the effect of gradation was eliminated by fabricating each of these mixtures the same. FL4, FL5, and FL6 have very high shear strengths. FL6 (crushed river gravel) and FL5 (Alabama limestone) are very hard aggregates with good angularity. FL4 (crushed PCC) is a weaker aggregate, but the particles have good angularity and very rough surface textures due to the porous cement matrix. The Florida limestones, FL1, FL2, and FL3, which have similar texture and shape, possess a range of shear strengths which appear to be related to particle strength.

Although it may be expected that the aggregate gyratory shear strength would be correlated to the particle index or LA abrasion value, Figures 44 and 45 show that no relationships are apparent. The lack of correlation between particle index and aggregate gyratory shear strength may be due to the fact that the aggregate gyratory shear strength is a measure of the frictional resistance of the overall gradation, whereas the particle index, as reported here, was only measured on the major aggregate size. Likewise, for aggregates which are very tough (i.e. low LA abrasion value), it may be anticipated that a very rigid interlock of particles may develop high internal shear strength. However, some aggregates that are not as tough in terms of LA abrasion value, such as FL4 and FL6, apparently have adequate particle strength and are able to develop excellent aggregate shear strength due to good surface texture, angularity, and gradation.

Shown in the second row of Table 28 is the dry VMA (DVMA) of the aggregate only from the GTM aggregate degradation test. Initially, DVMA was expected to provide an indication of the aggregate angularity and texture like the particle index test. However,

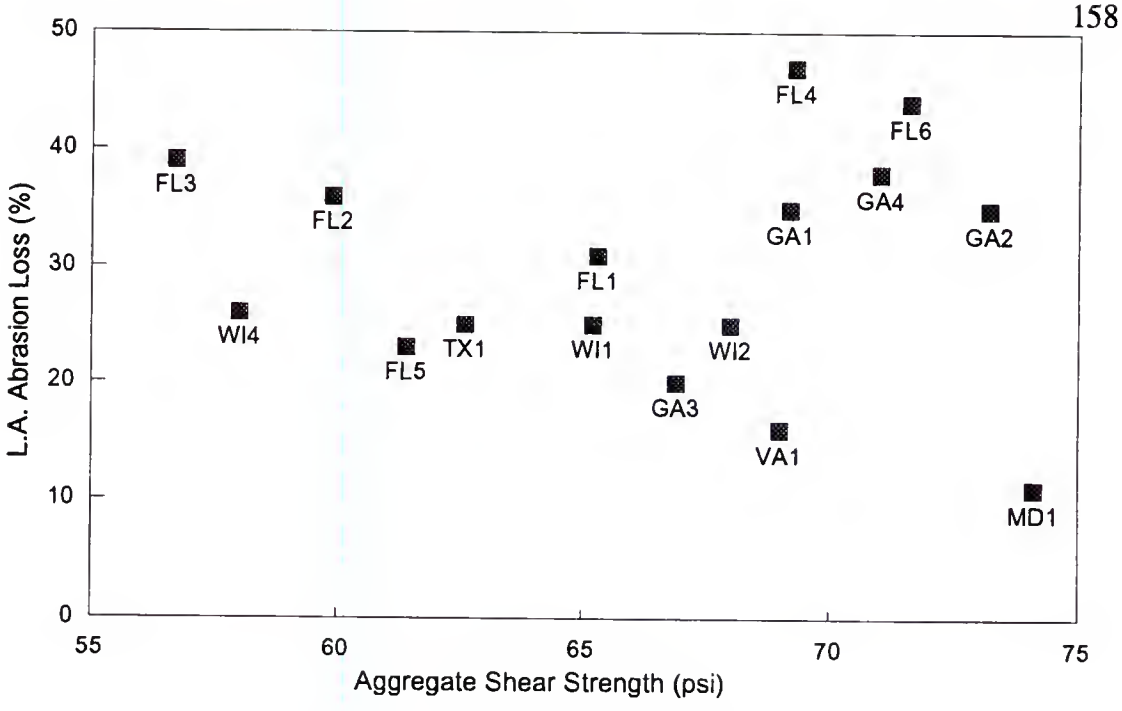

Figure 44. Plot of Gyratory Shear Strength of Aggregates versus L.A. Abrasion Values

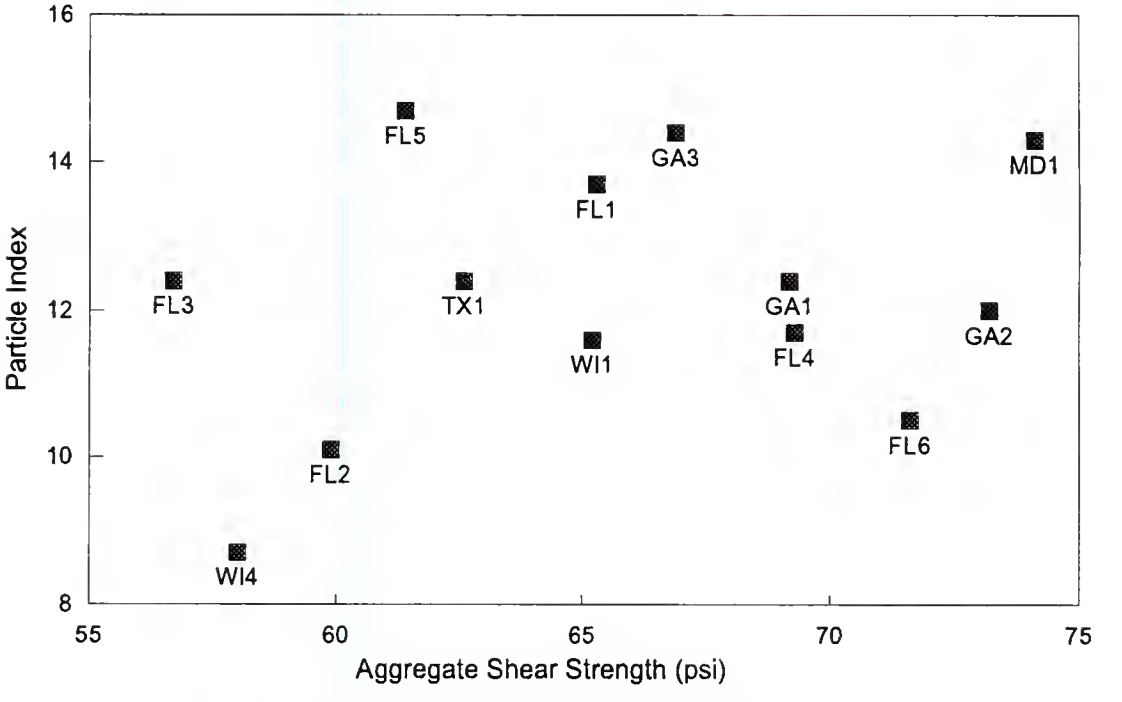

Figure 45. Plot of Gyratory Shear Strength of Aggregates versus Particle Index

DVMA is determined in the context of the whole gradation and better represents how the different size particles interact. The DVMA is therefore a measure of the total aggregate density in a well compacted state. The statistical comparison of the DVMA for the different aggregate mixtures is shown in Figure 46. This parameter also has a low coefficient of variation. From this bar graph it is evident that the gradation used in the experimental Florida mixtures produced a relatively low DVMA. However, the gradation is not the only factor responsible for the low DVMA's since mixture WI1 and MD1 had similar gradations but significantly higher DVMA's. Another factor which certainly influences how well the aggregate particles compact together is the resistance of the particles to degradation.

The first direct measure of degradation from this test is the Gyratory Degradation Index, GDI. GDI, which is the average absolute value change in percent passing each sieve in the gradation, is a measure of the overall change in gradation. The statistical comparison of GDI's for the study mixtures is shown in Figure 47. Several observations can be made from this chart. First, it is evident that LA abrasion is not correlated to GDI because FL5 and FL6 which have LA abrasion values of 23 and 41, respectively, are in the same Duncan grouping for GDI. Another example is TX1 and FL3, which are in the same Duncan group but have very different LA abrasion values. It is also apparent from comparing GDI results of GA1 and GA2, which contain the same aggregates, that gradation has a significant impact on GDI. Finally, this chart indicates that there are significant differences in degradation potential among the Florida aggregates. However,

General Linear Models Procedure

Dependent Variable: Dry VMA

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	15	89.4397	5.9626	0.656	13.86	0.0001

$\alpha = 0.05$
R-Square = 0.929
C.V. = 2.627

Duncan Grouping

Means with the same letter are not significantly different

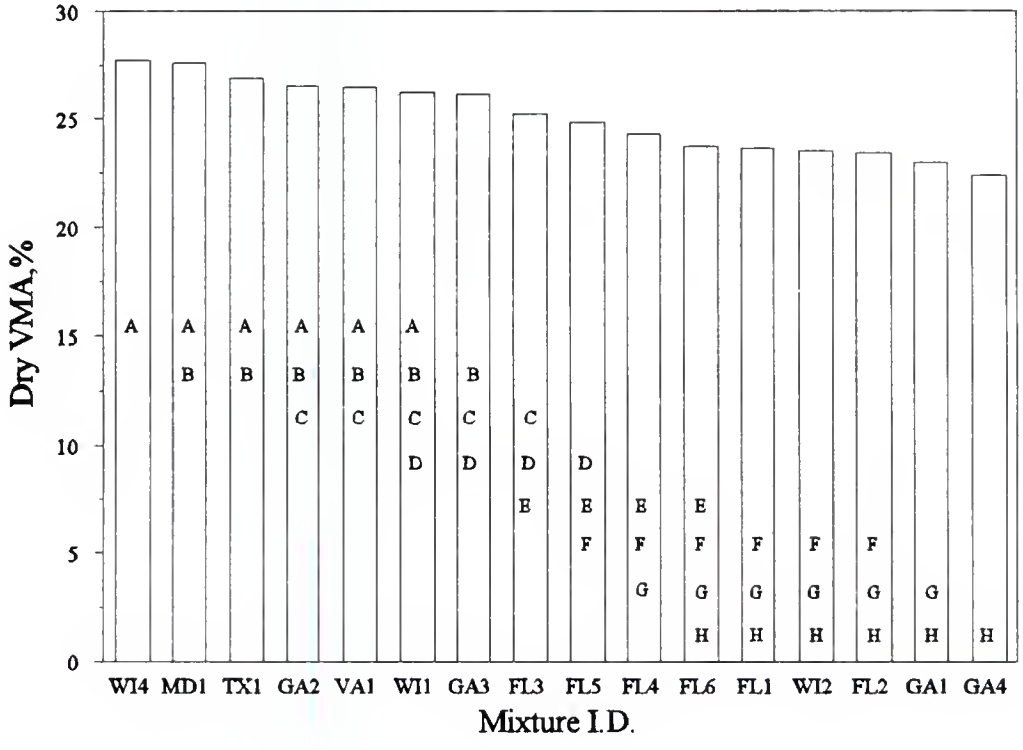

Figure 46. Comparison of Dry VMA Results

General Linear Models Procedure

Dependent Variable: Gyratory degradation index

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	14	9.889	0.659	0.125	42.19	0.0001

$\alpha = 0.05$
R-Square = 0.975
C.V. = 7.168

Duncan Grouping

Means with the same letter are not significantly different

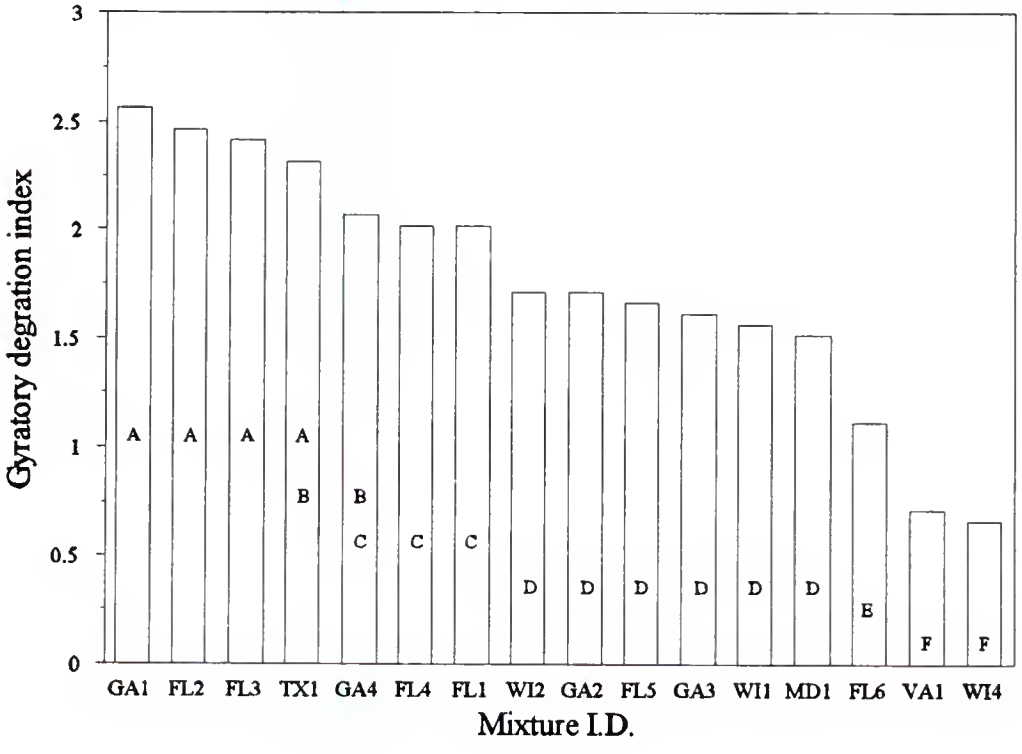

Figure 47. Comparison of Gyratory Degradation Indices

results for all of the aggregate blends using Florida materials are within the overall range of the materials used in the field mixtures.

The change in the calculated surface area, ΔSA, was also used as a measure of degradation. This data is shown in the fourth row of Table 28. Statistical comparisons of ΔSA are shown in Figure 48. This parameter, which is heavily influenced by the change in the percent passing the No. 200 sieve, yields different ranks and groupings than the gyratory degradation index. The fact that this parameter ranks the aggregates differently indicates that there are differences in the way some aggregates break-down during the test. For example, comparing TX1 with FL2 and FL3 shows that the have similar gyratory degradation indices, but the change in surface area for TX1 is significantly less than FL2 and FL3. This indicates that these two Florida limestone aggregates tend to break-down by generating finer material than with the Texas limestone.

Another parameter used to quantify aggregate breakdown from the gyratory aggregate degradation test was the change in percent passing of the major sieve, ΔMS. Statistical comparisons of ΔMS are shown in Figure 49. It can be seen that the rank of the study mixtures according to ΔMS is exactly the same as with GDI, although the statistical groupings are a little different. A plot of GDI versus ΔMS, shown in Figure 50, reveals a good correlation. A least squares linear regression yielded the equation shown below. The coefficient of determination (R^2) for this regression was 0.985. This

$$\Delta MS = 4.08(GDI) - 0.25 \quad (17)$$

General Linear Models Procedure

Dependent Variable: Change of surface area

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	15	222.770	14.851	0.488	62.45	0.0001

$\alpha = 0.05$
R-Square = 0.983
C.V. = 9.997

Duncan Grouping

Means with the same letter are not significantly different

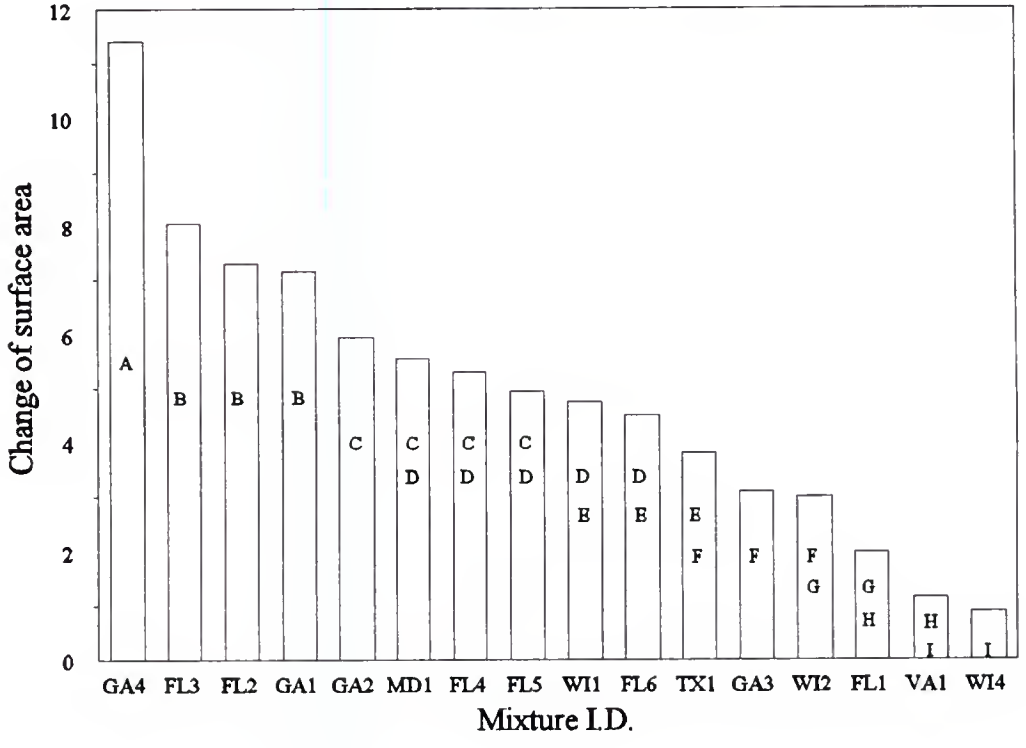

Figure 48. Comparison of Changes in Surface Area.

General Linear Models Procedure

Dependent Variable: Change in percent passing the major sieve

Source	DF	Type I SS	Mean Square	Root MSE	F Value	Pr > F
MIX	15	153.147	10.210	0.659	23.52	0.0001

$\alpha = 0.05$
R-Square = 0.957
C.V. = 9.640

Duncan Grouping

Means with the same letter are not significantly different

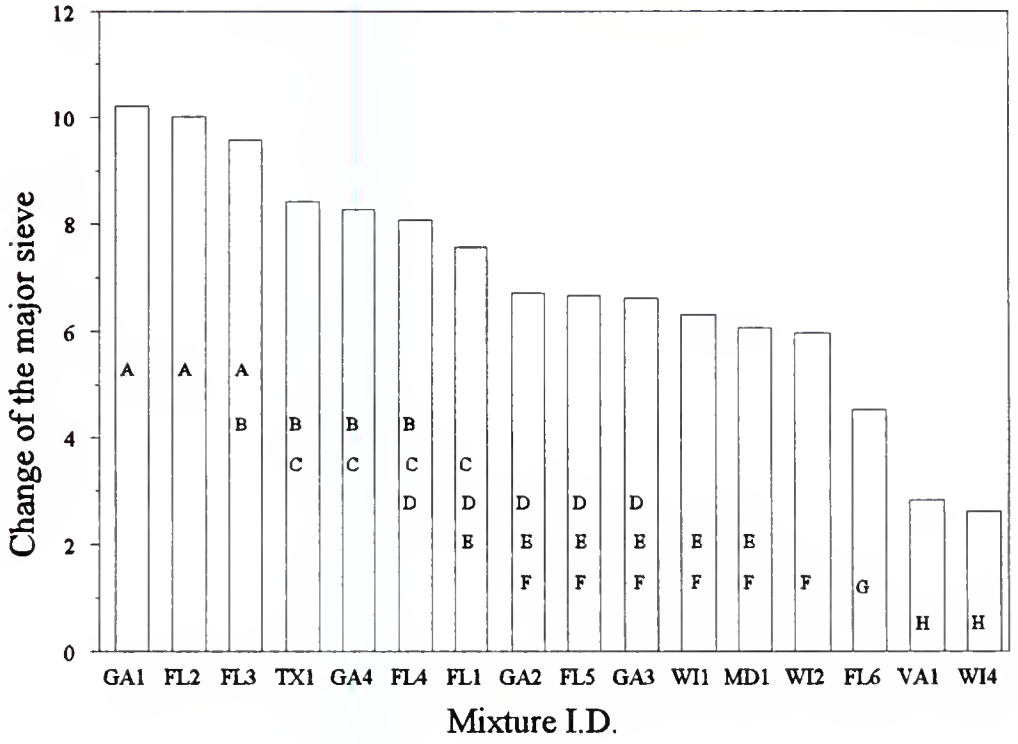

Figure 49. Comparison of Changes in Percent Passing the Major Sieve

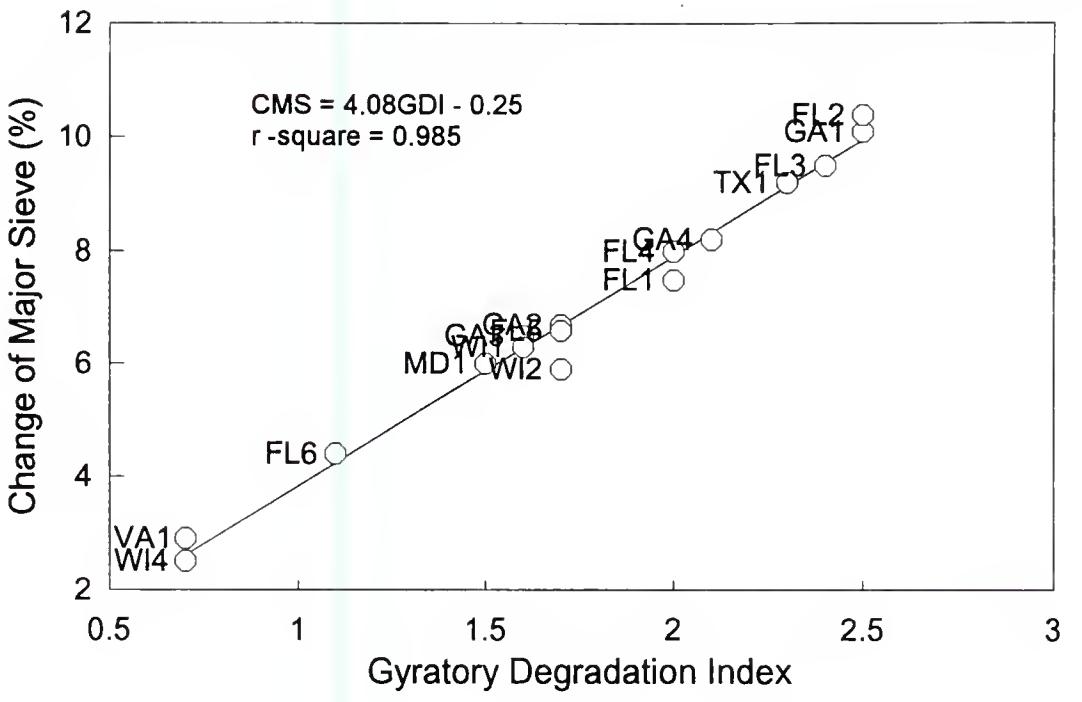

Figure 50. Plot of Gyratory Degradation Index versus Change in Major Sieve

correlation indicates that the two parameters GDI and ΔMS are almost redundant and that only two of the three GTM degradation parameters is necessary to characterize the aggregate break-down.

8.5 Correlation of Aggregate Characteristics to Mixture Test Results

A series of simple and multiple linear regressions were performed to relate aggregate characteristics to results of the mixture tests which were felt to be aggregate dependent. A data array of all aggregate test results and relevant mixture properties and test results was created to perform the analysis. Since there were a number of variables which contributed to mixture behavior, SAS procedure PROC REG along with R-SQUARE selection model and the C(p) statistic [55,56] were used to the obtain

optimum variables in each multiple linear regression. A number of step-type procedures that add or delete variables one at a time until a reasonable stopping point was reached was employed in determining suitable relationships [55,57].

Table 29 includes results of the regression analyses. As can be seen, the coefficients of determination range from 0.72 to 0.85, indicating that the identified variables account for 72 to 85 percent of the observed variation in the regressions' dependent variables. Based on the statistical analysis, the variables shown in bold have the greatest influence on the mixture property. These models are not intended to be used as prediction equations, but rather as evidence that certain aggregate characteristics significantly effect mixture behavior. In particular, the first six regressions relate aggregate characteristics to rutting resistance. Regression equations 7 and 8 relate aggregate characteristics to moisture damage resistance.

Equations 1 and 2 show that rutting resistance in the GLWT is partially controlled by mixture stiffness, but that aggregate parameters such as dry VMA, particle index, percent change in the major sieve, and aggregate gyratory shear strength also contribute. Contrary to the expected trend, the regressions indicate that higher DVMA and particle index, which should be those aggregates with good angularity and surface texture, cause lower rutting resistance. However, low DVMA can also result from a gradation in which aggregates fit tightly together and create many points of contact between particles. Hence, a relatively low DVMA, or high aggregate density, can provide better rutting resistance than gradations having high DVMA.

Table 29. Results of Aggregate-Mixture Regressions

Reg.#	Regression Equation	R^2
1	1/Rut = 0.04**MR40** - 0.78**DVMA** -1.01PI +0.52ΔMS +0.18GSA - 0.09LA + 25.05	0.76
2	1/Rut = 0.06**ITS** - 0.01MR40 + 0.34ΔSA + 0.16ΔMS + 0.08GSA + 0.08WL - 7.13	0.72
3	τG_{200} = -4.01**DVMA** - 0.32**LA** - 0.48ΔMS - 0.19PI - 0.39ACW +175.6	0.83
4	τG_{200} = -1.23**DVMA** - 0.43**LA** - 2.93VMA + 152.58	0.71
5	ϵ'_p = -0.03**ITS** + 2.02WL - 0.22ΔMS -0.01MR40 - 0.01GSA +7.75	0.72
6	$\log(1/\epsilon'_p)$ = 0.01**ITS** - 0.03**WL** + 0.14ACW + 0.05ΔSA + 0.02	0.81
7	TSR = 0.04Δ**SA** - 0.01**LA** - 0.03AV + 0.02ACW - 0.02ΔMS - 0.01GSA - 0.01WL + 1.39	0.77
8	MRR = -0.08**AV** - 0.05Δ**MS** - 0.06**Z** + 0.02ΔSA - 0.01LA + 0.01WL + 1.40	0.85

Definition of Variables

1/Rut - inverse of GLWT rut depths in inches
MR40 - resilient modulus at 40°C, ksi
DVMA - dry voids in mineral aggregate, %
PI - particle index of -⅜, +No.4 fraction
ΔMS - change in percent passing the major sieve, %
GSA - aggregate gyratory shear strength, psi
τG_{200} - GTM shear strength at 200 gyrations, psi
LA - Los Angeles abrasion loss, %
ACW - asphalt content by weight, %
ϵ'_p - triaxial repeated-load permanent strain rate, E-5/cycle
ITS - indirect tensile strength, psi
WL - weight loss, grams
ΔSA - change in surface area, $cm^3/100g$
Z - percent densification, %

According to these regressions, an increase in break-down on the major sieve (greater aggregate degradation) increases resistance to rutting. Another variable which indicates the influence of frictional resistance of the aggregate structure is the variable GSA. The regression shows that rutting resistance in the GLWT is improved with an increase in aggregate shear strength.

The dependent variable in regression equations 3 and 4 is gyratory shear strength of the mixtures at 200 gyrations. These regressions, like regression equations 1 and 2, indicate that shear strength decreases (i.e. rutting potential increases) as DVMA and PI increase. The regressions also indicate that aggregate degradation (LA and ΔMS) tends to decrease shear strength. It is interesting that mixture stiffness and tensile strength do not appear as significant variables in the regressions for gyratory shear strength as they do for the results of the GLWT or the triaxial repeated-load tests. This may be due to the rigid confinement of specimens in the GTM compared to the other permanent deformation tests in which the partial or limited confinement permits aggregate dilation and the development of tensile stresses in the zone of shear failure.

Regression equations 5 and 6 show that tensile strength has a significant influence on permanent strain rate. Excess binder, as quantified by weight loss, is shown to increase rutting potential. It can also be seen that aggregate degradation, indicated by ΔMS and ΔSA, has a negative impact on deformation resistance. These regressions again demonstrate that an increase in aggregate shear strength, GSA, increases rutting resistance.

Moisture damage resistance of the study mixtures were also affected by several aggregate characteristics. Regression equations 7 and 8 indicate that degradation of the coarse aggregate, indicated by LA abrasion loss and ΔMS, has a detrimental effect on TSR and MRR. On the other hand, the regressions also indicate that an increase ΔSA improves the moisture damage ratios. However, because of the interdependency of ΔSA,

ΔMS, LA and other varibales, this observation may be misleading. The regressions also indicate, as expected, that air void content is an important variable in the resistance of the mixtures' to moisture damage.

CHAPTER 9
ASSESSMENT OF TESTS AND MATERIALS

9.1 Assessments of Mixture Tests

9.1.1 Compaction

SMA mixtures can be satisfactorily compacted in the Gyratory Testing Machine using the procedure established by Ruth et al. [32]. This relatively simple procedure, which was recommended as part of the AAMAS study, better simulates the kneading action of steel wheel rollers than does hammer compaction. Compaction curves for the eleven duplicated field SMA mixtures showed the compactive effort necessary to achieve the initial field densities ranged from 5 to 20 gyrations in the GTM. The wide range of compactive efforts demonstrates the fact that different SMA mixtures have varying degrees of compactability dependent on aggregate characteristics and stabilizing additives. A reasonable standard compactive effort can be accomplished with 12 gyrations of the GTM, with the initial air roller pressure at 9 psi and the ram pressure at 100 psi.

9.1.2 Rutting Tests

Of the three tests used to characterize rutting potential (the GTM densification/shear test, the Georgia loaded wheel test and the triaxial repeated load test), the GTM test had the lowest coefficient of variation. This test is also the easiest of the three to perform. However, its repeatability is a concern. Retests on a couple of mixtures

yielded significantly different results. It also appears that the GTM test, like many other tests, is very dependent on the technique of the operator.

The Georgia Loaded Wheel test is fairly easy to perform and interpretation of the results is intuitive and can be visually confirmed. However, it suffers from high variability and the time to complete a set of beams for one mixture is excessively long (approximately one week).

Variability of the triaxial repeated-load test is also higher than desired. The initial set-up for this test was very time consuming, but once the test hardware and software were integrated with the MTS station, performing the tests and analysis of the results were not complicated. Based on the work of Gabrielson [35], the triaxial repeated-load test probably has the strongest correlation to field performance.

Due to the scarcity of field performance data on the study mixtures at the time this dissertation was prepared, correlations of the rutting tests to field performance was not possible. However, the perception that the field SMA mixtures are performing well, especially with respect to rutting, was validated for most mixtures by the three rutting tests. It appears that most of the criteria used to judge dense-graded mixtures are appropriate for SMA mixtures. The exception to this general statement is the densification parameter from the GTM densification/shear test. The data indicates that the consolidation of SMA mixtures to low air void contents is not necessarily detrimental to gyratory shear strength. Therefore, the criteria to ensure a high degree of rutting resistance for SMA mixtures are: $\tau G_{200} \geq 54$ psi, GLWT rut depth at 8000 cycles ≤ 0.15 inches, and $\epsilon'_p \leq 3.66$ E-6/cycle in the presented triaxial repeated-load test.

9.1.3 Resilient Modulus

The diametral resilient modulus test was a fairly simple test to perform using the MTS station and software. Repeatability of the test data was very good. Coefficients of variation at each of the three test temperatures was less than 8 percent. The data shows that SMA mixtures tend to have lower moduli than typical of dense-graded mixtures. The validity of the resilient modulus test for SMA mixtures, particularly at higher temperatures, has been questioned. Furthermore, the utility of the test as part of routine SMA mix design was not established. Resilient modulus appears to indicate the relative stiffness of the binder or mastic in the SMA mixtures. However, resilient modulus by itself, is not indicative of mixture performance.

9.1.4 Indirect Tensile Strength Test

The indirect tensile strength , strain at failure, and fracture energy were also easily measured with the MTS station and modified software. The analysis of variance for each of these parameters showed that the coefficients of variation were 8.99, 13.42, and 13.28, respectively. The tensile strengths appear to be affected by air void contents of the samples. Tensile strengths, and failure strains also appear to indicate the effect of the mastic in the SMA mixtures. For example, some stabilizers, such as Novaphalt + mineral fibers, and ground tire rubber appear to produce relatively high tensile strengths, but result in relatively low failure strains.

Based on a fatigue evaluation from the AAMAS study using resilient moduli and failure strains at 25°C, most of the study SMA mixtures have lower fatigue cracking

resistance than the standard dense-graded mixtures. This analysis indicates that the SMA mixtures with high failure strains (≥0.9 %) generally have satisfactory fatigue behavior. It is not known whether or not this is a fair evaluation of the fatigue resistance of SMA mixtures. Certainly, the low resilient moduli of SMA mixtures relative to dense-graded mixtures contributes to the lower fatigue assessment. Since there are many factors which affect fatigue life of asphalt mixtures, this technique should only be used as a preliminary technique for indicating the relative fatigue behavior of SMA mixtures. It should also be considered that fatigue is not a major concern for surface mixtures.

9.1.5 Creep Compliance

The diametral creep test used in this study suffered from large variability. Although the slopes of the creep compliance - time curves did indicate that some binder additives may become very stiff with little viscous relaxation at a moderately low temperature, acceptable values for compliance slopes were not found in the literature and the data did not reveal an obvious limit. Low temperature cracking has not been reported for any of the duplicated field mixtures. Therefore, the current creep test does not appear to be warranted as part of routine SMA mix design. However, the creep test may be useful in evaluating the relative performance of competing stabilizing additives. One advantage of the test is that it is non-destructive, so the samples could be used for other tests as well.

9.1.6 Moisture Damage Resistance

The tests used in this study to evaluate moisture damage potential were the resilient modulus ratio and tensile strength ratio. The tensile strength tests were much easier to perform. Comparison of variabilities for the two methods was not possible since an analysis of variance could not be performed on the TSR results. The resilient modulus data does indicate that the temperature sequence of testing conditioned samples may affect the results. Most of the study SMA mixtures, excluding the experimental Florida mixtures, had MRR's and TSR's greater than 80 percent. Since none of these mixtures have been reported to have problems with moisture damage, the commonly used 80 percent criteria appears to be suitable. Based on its history and simplicity, the wet-dry tensile strength ratio is a good test to be included in routine testing of SMA mix designs.

9.2 Assessment of Study Mixtures

9.2.1 Compaction and Volumetric Properties

The mixtures duplicated from the field projects and the experimental mixtures represent a wide range of materials and gradations. Consequently, the physical properties of the mixtures varied substantially. Gradations of the duplicated field mixtures ranged from 45 to 26 percent passing the No.4 sieve. Asphalt contents ranged from 5.5 percent to 6.4 percent. The TWG recommended minimum asphalt content is 6.0 percent. Seven of the eleven field mixtures had lower asphalt contents. Average in-place air void contents of the SMA field mixtures ranged from 5.0 to 10.5 percent, although most were between 6 and 8 percent. Average air void contents of the GTM compacted samples ranged from

4.1 to 9.9 percent, with most mixtures having between 6 to 7.5 percent air voids. Excluding GA1, the compacted VMA's ranged from 17.7 to 21.3 percent. Effective asphalt contents, based on volume, ranged from 11.3 to 14.9 percent.

The experimental mixtures containing typically used aggregates in Florida had asphalt contents from 4.7 percent for the river gravel mixture to 6.2 percent for the Taylor Co. limestone mixture. Average compacted air void contents ranged from 6.4 percent to 7.3 percent. Effective asphalt volumes were from 8.1 to 11.0 percent, which are all below the range of the field mixtures. VMA's were also lower, ranging from 15.1 to 17.4 percent. The low VMA's are a result of the standard gradation used in the experimental mixture. VMA's could be increased by targeting a lower percentage passing the No.4 sieve and reducing the mineral filler content slightly. This would allow for more asphalt in the mixtures and may improve the mixtures' resistance to fatigue and moisture damage.

9.2.2 Rutting Potential

Results indicate that most of the duplicated field mixtures and most of experimental mixtures are highly resistant to permanent deformation. Several mixtures did appear to have excess asphalt based on flushing of the mastic during the densification/shear test. Several mixtures also densified to relatively low air void contents. However, most of these mixtures maintained good shear resistance. Mixtures GA1 and GA2 are among the best mixtures in all three rutting tests. At the other end of the range, TX1 appears to most susceptible to rutting. However, even this mixture could be considered marginally poor based on gyratory shear strength and GLWT rut depths. A

0.5 percent reduction in binder content would probably improved the rutting resistance of this mixture without a significant sacrifice in durability.

Of the mixtures containing Florida aggregates, FL1 (Dade Co. limestone) and FL2 (Hernando Co. limestone) appear to have excellent rutting resistance based on results of the three tests. Mixture FL5 (Alabama limestone) had high gyratory shear strength and satisfactory results in the loaded wheel test, but poor results in the triaxial repeated-load test. The other experimental mixtures, FL3 (Taylor Co. limestone), FL4 (crushed PCC) and FL6 (crushed gravel) had results that were generally among the middle of the range for each test and are considered to have good rutting resistance.

9.2.3 Resistance to Fatigue Cracking

Based on the fatigue evaluation criteria from the AAMAS project, the majority of the SMA mixtures included in this study appear to have marginal to poor fatigue resistance. This assessment is largely a result of the relatively low resilient moduli for the SMA mixtures. The other parameter used in the AAMAS fatigue evaluation, strain at failure, appeared to distinguish which mixtures had good or poor fatigue resistance. According to the AAMAS technique, mixtures which had acceptable fatigue resistance were GA4, WI3, MD1, VA1, TX1. None of the experimental Florida mixtures appeared to have good fatigue resistance, although mixture FL5 was very close. It is interesting to note that mixtures which appeared to have better fatigue resistance generally had marginal to poor rutting performance as indicated by one or more of the rutting tests. This

demonstrates the often precarious balance of mix design between deformation resistance and durability.

9.2.4 Low Temperature Cracking Potential

Assessment of thermal cracking potential for the study mixtures is limited to relative comparisons of creep compliance slopes. Mixtures with higher slopes would more readily strain and minimize the accumulation of tensile stresses due to pavement contraction at low temperatures. The study mixtures with the highest creep compliance slopes include FL3, VA1, WI3, FL4, and GA4. However, due to the variability of the data, comparisons showed very broad groupings. The results do appear to indicate that stabilizing additives such as Novophalt and Vestoplast become very stiff and potentially brittle at low temperatures. Other additives, such as SBS which was used in GA4, and ground tire rubber which was used in the Florida mixtures, appear to result in a binder that remains more ductile at relatively low temperatures.

9.2.5 Moisture Damage Potential

Most of the duplicated field mixtures appear to be very resistant to moisture damage. The two exceptions were GA3, which contains a granite with a history of stripping, and WI2, which had an excessively high air void content and was therefore more susceptible to water intrusion. All of the experimental Florida mixtures also appear to be susceptible to moisture damage based on either a low resilient modulus ratio or a low tensile strength ratio, or both. It is believed that the stripping potential of these mixtures

could be remedied by using an anti-stripping additive and or by increasing the asphalt contents.

9.3 Assessment of Aggregate Tests

9.3.1 LA Abrasion

SMA mixtures should require tougher aggregates. Although, the L.A. abrasion test does not correspond to the actions causing degradation during placement, compaction and under traffic, it may represent the breakdown of coarse aggregates passing through the asphalt plant's drum/dryer. Correlations of aggregate characteristics to mixture test results indicated that L.A. abrasion has a minor affect on rutting resistance and moisture damage potential. However, good SMA mixtures have been designed with aggregates having relatively high L.A. abrasion values. Therefore, L.A. abrasion should be used as a criteria, but the limit should be raised or exceptions made for aggregates which have acceptable performance histories.

9.3.2 Flat & Elongated Particles

The specification for flat and elongated particles is generally not difficult to meet and is therefore not disputed. This is a very simple, quick and inexpensive test. Although the sensitivity of mixture performance to flat and elongated particles is unknown, it is intuitively recognized that more cubical or equidimensional particles are desirable in asphalt mixtures including SMA mixtures.

9.3.3 Sulfate Soundness

The sulfate soundness test is intended to protect against aggregates susceptible to freeze-thaw damage. It has been loosely used as a measure of general aggregate quality. However, no data or reasoning has been provided in the literature to support the sulfate soundness criteria in the TWG specifications. Due to the very low permeability of asphalt pavements and the temperate climate of Florida, it has been the policy of the FDOT that sulfate soundness is not required for aggregates used in asphalt mixtures. This logic should apply to aggregates for SMA mixtures as well.

9.3.4 Crushed Faces

The procedure for determining the percentage of fractured or crushed faces has not been standardized, and therefore this requirement is subject to broad interpretation. For instance, what constitutes a fractured face? Generally, meeting the specification is not very difficult for well crushed aggregates and assuming a reasonably conservative or strict interpretation. However, many river gravel particles will be counted as having two crushed faces, yet, half or more of the particles' surface will be rounded. Two mixtures in this study, WI4 and FL6, contained river gravel with some rounded particles. Instructions for conducting the test should be included when the fractured faces requirement is specified. Also, a further requirement of at least 80 percent of the particles with three fractures faces would better assure good, angular coarse aggregate particles in this aggregate dependent mixture.

9.3.5 Absorption

Aggregate absorption is recognized to be both advantageous and detrimental. On the beneficial side, absorption of asphalt into surface pores of the aggregate is believed to create a good mechanical bond which will be more resistant to stripping. On the other hand, absorptive aggregates will require slightly higher asphalt contents in order to maintain a specific effective volume of asphalt or film thickness. It is believed that the intent of the limit on absorption was set to assure a minimum effective asphalt content. A more logical approach is to directly specify a minimum effective volume of asphalt rather than a minimum asphalt content by weight and a maximum aggregate absorption.

9.3.6 Index of Particle Shape and Texture

This test appeared to have good potential for providing a relative indication of aggregate shapes and surface textures. Particle indices of the -3/8", +No.4 sieve fraction of many of the aggregates appeared to correspond with the visual assessment of the angularity and texture of the particles. Correlations presented in Chapter 8 indicated that particle index was inversely related to rutting resistance. However, a direct comparison of particle index results to GLWT results and gyratory shear strength did not indicate any trend.

9.3.7 GTM Aggregate Degradation Test

Several parameters from the GTM aggregate degradation test were found to affect the resistance of SMA mixtures to rutting and moisture damage. This very simple test is unique in that the evaluation is made on the actual blend of aggregates at the proposed

mixture gradation and therefore it inherently accounts for the interaction and packing effects of the different particle sizes. Four independent parameters were identified: aggregate gyratory shear strength (GSA), dry VMA (DVMA), change in percent passing the major sieve (ΔMS), and change in surface area (ΔSA). The variability for each of these parameters is considered acceptable. From the analysis of the data, the most useful parameters appear to be DVMA and ΔMS.

DVMA is a measure of the relative aggregate density and was shown to affect rutting resistance. SMA mixtures with higher aggregate densities (low DVMA) tended to have lower rut depths in the GLWT and high shear strengths in the GTM densification/shear test. The change in percent passing the major sieve, ΔMS, is an indicator of the coarse aggregate degradation resulting from contact stresses between particles. Comparison of data from the GTM aggregate degradation test to L.A. abrasion values illustrated that breakdown of aggregates under high particle to particle contact stresses can be very different than breakdown due to impact and abrasion. Although the effect of breakdown of the major aggregate size on rutting resistance was inconsistent, mixtures with more coarse aggregate breakdown were more susceptible to moisture damage. It is probable more coarse aggregate breakdown would also make the mixture more prone to ravelling. Evaluation of aggregate degradation and its effect on performance in field projects is needed to establish limits. Further research is also necessary to more thoroughly assess these variables with alternate gradations and other binder contents.

9.4 Assessment of Florida Aggregates

9.4.1 Dade County Limestone

This aggregate fails the TWG guide specification on absorption and barely fails on LA abrasion loss. Based on the laboratory tests performed in this study, the experimental mixture with this aggregate (FL1) appeared to perform as well or better than many of the field SMA mixtures, despite having low VMA and effective asphalt content. The particle index test indicated that the -3/8, +No.4 fraction has good surface texture and angularity. The results of the GTM degradation test showed that this aggregate was fairly resistant to degradation. It had the lowest ΔMS of the Florida limestones and had the lowest ΔSA of all of the Florida aggregates. This aggregate also has the advantage of good skid resistance and history of use in open-graded friction course mixtures.

9.4.2 Hernando County Limestone

This limestone did not meet the SMA aggregate requirements for L.A. abrasion, absorption, and the exclusion of pure carbonate materials. It was also among the most susceptible to degradation in the GTM aggregate degradation test and it had a low aggregate shear strength. However, it was able to develop a relatively low DVMA (high aggregate density) which is likely why it was able to perform very well in the rutting tests. On the other hand, due to the amount of breakdown which occurred for this aggregate, it may be more prone to moisture damage and ravelling. Since it is a soft, pure limestone, it would also be expected to polish quickly and a friction course would be necessary over SMA mixtures with this aggregate.

9.4.3 Taylor County Limestone

The Taylor County dolomitic limestone also failed to meet most of the TWG aggregate guidelines. It was similar to the Hernando County limestone in its susceptibility to breakdown in the GTM. However, it had a lower aggregate density (higher DVMA) and its aggregate shear strength was lower which caused the experimental mixture with this aggregate (FL3) to have less resistance to rutting. Mixtures with this aggregate would also be susceptible to moisture damage, ravelling, and loss of skid resistance.

9.4.4 Gator Asphalt Co. Crushed PCC

Characteristics of this aggregate range from good to average to poor. The L.A. abrasion value and absorption for this aggregate are the highest of the study materials and are well above the TWG's maximum limits for SMA aggregates. The degradation of this material in the GTM was a little more than for most of the field mixtures, but not as much as the pure carbonate aggregates in Florida. Aggregate shear strength of the PCC gradation was high. Results of tests on the SMA mixture containing this aggregate (FL4) were also mixed. Gyratory shear strength, τG_{200}, was marginal, but GLWT results and triaxial repeated load test results were good. Moisture damage for this mixture was substandard. The polish resistance of this aggregate is unknown.

9.4.5 Shelby County, Alabama Limestone

This aggregate meets all of the requirements of the TWG specifications except for the exclusion of pure carbonate aggregates. However, this guideline was also disregarded

in several of the field mixtures included in this study, namely WI1, WI2, WI3, and TX1. This aggregate had a high particle index and aggregate shear strength. It was also resistant to degradation in the GTM. Therefore, it was expected the mixture containing the Alabama limestone (FL5) would be a very rut resistant mixture. However, the results of the rutting tests for this mixture were conflicting: τG_{200} was high, GLWT rut depths were acceptable but marginal, and the permanent strain rate in the triaxial repeated-load test was poor. Some improvement in the rutting resistance of this mixture may have been possible by reducing the binder content without sacrificing the resistance to cracking and moisture damage.

9.4.6 Chattahoochee River Gravel

The crushed river gravel meets the TWG guide specifications except for L.A. abrasion loss. However, the results of the crushing strength test and the GTM test show that these quartz gravel particles are very hard and resistant to crushing and degradation. The disadvantage of this aggregate is the presence of rounded and partially rounded particles. Consequently, its particle index was low and the rutting resistance of the mixture (FL6) was generally marginal to poor. This aggregate was used in open-graded friction course mixtures prior to 1994 and is known to have good friction and wear characteristics. However, its use in this application was discontinued due to chronic ravelling problems that were due to poor bonding between the asphalt and the aggregate which was compounded by the rapid aging of the binder in the open-textured mixture.

CHAPTER 10
IMPACT OF SMA MIXTURES ON FLORIDA

10.1 Cost Analysis

For the purpose of this cost analysis, it will be assumed that SMA mixtures will be used in Florida and consequently, it can have an impact on the paving industry. Therefore, it must first be established that SMA mixtures are, or are not, economical in comparison to conventional paving mixtures. Theoretically, the best comparison between SMA mixtures and conventional mixtures would be a life cycle comparison. However, life cycle costs for SMA mixtures can not be determined because the life expectancy of an SMA pavement is unknown. European highway agencies claim that SMA pavements last longer than conventional asphalt pavements, but no definitive data is available.

Therefore, a comparison based on initial costs is the only option. However, an initial cost comparison will also have uncertainty since production costs of SMA mixtures in Florida can only be estimated.

Several other states have now gained enough experience with SMA mixtures to begin specifying SMA mixtures for entire projects rather than just in test sections. Prices of SMA mixtures on these large projects should reflect realistic material and production costs since they have been competitively bid. In Georgia, which has let several large projects including 62,000 tons of SMA on Interstate 85 in Savannah, the cost per ton of

SMA has been from $44 to $48 as compared to $30 to $35 per ton for conventional asphalt mixtures. Maryland, which has placed nearly 400,000 tons of SMA, has received bid prices ranging from $38 to $50 per ton for SMA mixtures, as compared to the mid 30's for conventional asphalt mixtures. The wide range in prices for SMA mixtures was attributed to the cost of different additives and other non-mix factors such as night paving and weather limitations. In Illinois, in-place costs of SMA mixtures with cellulose fibers have been around $42.00 per ton, with mineral fibers the price has been $44.25 per ton, and with polymer modified binders the price has been up to $60.00 per ton.

Perhaps the best estimate for the cost per ton of SMA mixtures in Florida can be based on the price of FDOT's open-graded friction course (FC-2). Like FC-2, SMA mixtures are all-virgin aggregate mixtures produced using aggregates from select sources. Also, they contain a stabilizing additive to mitigate draindown. In fact, a variety of laboratory tests performed in concert with, but not part of this research, have shown that twelve percent ground tire rubber (GTR), such as used in FC-2 mixtures, is one of the best stabilizing additives and binder modifiers for SMA mixtures.

At the time this dissertation was written, the average statewide average cost of FC-2 mixtures was $1.30 per square yard based on bid prices from the previous twelve months. This period of time includes the initial GTR demonstration projects and the implementation of the GTR process. The cost has declined over the most recent months as contractors become more familiar with the process and the initial investments in new equipment have been made. As the supply market for the ground tire rubber becomes

more competitive, it is expected that the price of FC-2 mixtures will continue to drop. Within the next year, the price of FC-2 should stabilize around $1.15 per square yard.

Converting this price to a tonnage basis is as follows:

$1.15/sy * 1 sy/50lbs * 2000 lbs/ton = $46.00/ton

It is therefore assumed that the cost per ton of SMA in Florida will be about $46.00. This compares to $29.19 per ton for dense-graded structural mixtures (Type S) based on the previous twelve months bid prices. These prices appear reasonable compared to the range of competitively bid prices for conventional and SMA mixtures in other states.

10.1.1 SMA With No Friction Course

An advantage SMA mixtures may have is that they may not require a friction course. Most SMA mixtures have been used as the pavement surface course and have provided excellent macrotexture to resist hydroplaning. SMA mixtures containing polish resistant aggregate should provide skid resistance equal to Florida's current FC-2 mixtures. In this scenario, the cost of SMA per square yard versus the combination of an equivalent structural value of FC-2 plus Type S mixture can be made. Using a typical thickness of 1.5 inches (150 lbs/sy) for SMA mixtures, the cost per square yard is as follows:

SMA: $46.00/ton * 1 ton/2000 lbs * 150 lbs/sy = $3.45/sy

The structural equivalent of the 1.5 inches of SMA would be 1.5 inches of Type S mixture. The FC-2 has no structural value. Therefore, the cost per square yard for an equivalent conventional structure is as follows:

Type S + FC-2: \$29.19/ton * 1 ton/2000 lbs * 150 lbs/sy + \$1.15/sy = \$3.34/sy

This comparison shows that the initial, in-place cost of SMA mixtures in Florida should be very similar to an equivalent combination of currently used mixtures. Therefore, for SMA mixtures with good skid qualities, the economic feasibility based on initial costs only appears to be favorable.

10.1.2 SMA With Friction Course

In the cases where the SMA mixtures contain polish susceptible aggregates, such as typical Florida or Alabama limestones, a friction course would be necessary to provide a safe and skid resistant pavement surface. For these situations, the cost per ton of conventional mixtures and the estimated cost of SMA mixtures can be directly compared. However, if it is true that the SMA mixtures perform better and last longer, these mixtures may prove to be more cost effective in the long run. An estimate of how much longer an SMA pavement would have to last to balance the higher initial cost can be determined by engineering economic analysis.

The current generalized unit cost for resurfacing expressway-type pavements is \$104,000 per lane mile [58]. Recent pavement performance data indicates that the typical

life of resurfacing projects on Florida's interstate highways is about 12 years. Therefore, assuming seven percent interest, the mean annualized cost of resurfacing for interstate pavements is:

A / P=$104,000, i=7%, n=12 A=$104,000 (0.1259) = $13,093.60 / lane mile / year

Now, given that SMA costs $3.45/sy and conventional Type S hot mix is $2.19/sy, the difference in cost per square yard is $1.26. Multiplying this by 7040 sy/lane mile gives an increase in initial cost of resurfacing with SMA of $8,870.40/lane mile. Thus, the total initial cost of resurfacing using as SMA is $104,000 + $8,870.40 = $112,870.40/lane mile.

Now, given the same annualized cost and interest rate, and solving for "n"

A/P = 13,093.60/112,870.40 = 0.1160 → n = 13.7 years

Therefore, SMA mixtures which require an FC-2 would have to last only 1.7 years (20 months) more, on average, to be economically justified.

10.2 Projecting SMA Usage

Since it is impossible to predict many of the circumstances that will affect the success or failure of implementation of SMA in the field, two projections have been made: an optimistic projection in which SMA gains acceptance over a period of a few years, and

a pessimistic projection in which the technology fails to prove economically or technically viable.

Table 30 summarizes the two scenarios over the next couple of years. Assumptions made in these projections are as follows:

1. Each test section will be one mile in length and one lane.
2. Projects are assumed to be seven miles in length, with four lanes (i.e. 28 lane miles)
3. In-place density for SMA mixtures is assumed to be 140 pcf.
4. SMA mixtures will be placed 1.5 inches thick.

Table 30. Projected SMA Usage in Florida

		Optimistic Projection			Pessimistic Projection		
Year	Description	Number	Lane Miles	Tons	Number	Lane Miles	Tons
1995	Test Sections	6	6	3,282	4	4	2,188
1996	Projects	3	84	45,948	1	28	15,316
1997	Projects	6	168	91,896	3	84	45,948
1998	Projects	10	280	153,160	0	0	0

As with any new paving technology, implementation will occur over several years to allow for assessments and adjustments. In the first year, experimental test sections will be necessary to verify this laboratory study. Comparison sections with several aggregate sources, and possibly with different stabilizing additives, will likely be constructed. Depending on the positive or negative aspects of the constructability and early performance of these sections, the number of full-scale SMA projects constructed the next

year will vary. The full-scale projects constructed entirely with SMA mixtures as the surface layer should provide suitable real cost data for initial cost comparisons with conventional construction.

It is expected that SMA mixtures would be used primarily on heavy traffic routes. It is also recognized that SMA mixtures will be competing with SHRP mixtures in the near future. Currently, of the state's 37,780 lane mile highway system, about 13,900 lane miles are categorized as "Intrastate" highways. Intrastate highways include Interstate highways, the Florida Turnpike and selected arterials. These are the heavy traffic routes.

Projections of the FDOT's resurfacing program [58] are to resurface approximately 2,200 lane miles of the state highway system per year beginning in mid 1996. Resurfacing on Interstate routes and the Turnpike will account for 677 lane miles in 1996 and 480 lane miles each year thereafter. Additionally, new construction in the Intrastate classification is projected at 48 lane miles in 1996/1997, 124 lane miles in 1997/1998, and 96 lane miles in 1998/1999. Assuming an optimistic projection of SMA implementation, by 1998, SMA mixtures could be used on nearly half of the resurfacing projects or new construction on heavy traffic routes.

In terms of tonnage, SMA mixtures will have much smaller impact. Currently, about 4.5 million tons of hot mix asphalt are placed on the state's highway system per year. It is expected that this quantity will increase along with the projected increase in the resurfacing program over the next few years. Assuming about a ten percent increase in the yearly tonnage to 5 million tons, and using the projected 1998 tonnage of SMA at

153,160 tons, SMA mixtures will only account for about three percent of the yearly HMA production.

10.3 Effects on Materials Supply

The narrow gradation range for SMA mixtures greatly limits the aggregate products that will be able to be used. Many of the trial SMA mixtures placed in the U.S. have contained specially screened aggregates. From an economic standpoint and for aggregate production logistics it would be desirable to utilize currently available aggregate products if they can meet the gradation and other necessary requirements. To meet the gradation limits, an SMA mixture will generally consist of one or two coarse aggregates that are uniformly graded to contain two size-range particles, a coarse sand or screenings, and a mineral filler. In most cases, the uniformly graded coarse aggregates will comprise between 75 to 80 percent of the mixture, sand or screenings will be about 10 to 15 percent, and mineral filler will be about 10 percent.

Using the FDOT's aggregate control database, a review was made of the approved coarse aggregate products to determine if materials were available which could be used to meet the SMA gradation requirements. More specifically, materials were sought which had between 90 and 100 percent passing the ½ inch sieve and 20 percent or less passing the No. 4 sieve. Thirty-one products were identified, including 19 products from 12 different mines in Florida. Suitably graded materials originating from outside the state included aggregates from Alabama, Georgia, Mexico, and Nova Scotia. The most useful aggregates from this size group would be those which had roughly equal portions retained

on the ⅜ inch sieve and the No. 4 sieve. Only eight currently available products were found with these proportions. However, considering the estimated tonnage of SMA in Florida for the next few years, it is expected that the supply of suitable aggregates could easily meet the projected demand. Even if other physical properties or performance in field trails necessitated the limitation of aggregates for SMA mixtures to a few sources, the limited application of SMA to relatively high traffic roadways would have a negligible effect on the aggregate market.

CHAPTER 11
CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

1. SMA mixtures generally appear to be highly rut resistant. Each of the eleven field SMA mixtures duplicated in this study have been reported to be performing well after two to four years of service. A few of these projects have had early signs of flushing, but deformations were not associated with these occurrences.
2. The gyratory compaction procedure recommended by Ruth et al. [32], which was included as part of the AAMAS mix design procedure for dense-graded asphalt mixtures, can also be used for compaction and design of SMA mixtures with minor modifications. This type of compaction has been shown in other research to better simulate field compaction by providing realistic aggregate orientation and close reproduction of physical properties.
3. Each of the three rutting tests used in this study (the GTM densification/shear test, the Georgia loaded wheel test, and the triaxial repeated-load test) will provide an indication of the rutting resistance of SMA mixtures. Use of one or more of these tests during SMA mix design is recommended for checking the adequacy of the recipe based gradation and volumetrically determined binder content.

4. In evaluating the rutting potential of SMA mixtures, the criteria propsed for the three tests are the same as previously established for dense-graded mixtures. This offers an advantage of being able to directly compare SMA mixtures to dense-graded mixtures.

5. The rutting resistance of SMA mixtures do not appear to be sensitive to low air void contents. This was demonstrated in the GTM densification/shear test in which many of the mixtures consolidated to low air voids (<2.5%) but maintained stable shear strengths. This characteristic has been observed by others in laboratory tests [7,24,26,28] and in the field projects were flushing was not accompanied by rutting.

6. Resilient moduli of SMA mixtures tend to be low relative to the range of resilient moduli typical of dense-graded asphalt mixtures. The stress and strain calculations for the indirect tensile loading condition may not be theoretically valid for binder rich mixtures like SMA when there is evidence of non-elastic deformations. However, the test does appear to indicate the relative temperature-stiffness behavior of the mastics and may be useful in making comparisons among SMA mixtures.

7. Tensile strengths and failure strains for SMA mixtures can be useful in evaluating different stabilizers. Some stabilizing additives tend to stiffen the binder which may help resist permanent deformation, but may make the mixture more prone to cracking. Other additives may produce the opposite effects.

8. Analysis of fatigue potential using the criteria reported in the AAMAS study indicates that many of the SMA mixtures evaluated in this study have low fatigue resistance. This assessment is suspected to be inaccurate since the criteria is dependent on resilient moduli which tend to be low for SMA mixtures. However, the SMA mixtures which did pass the criteria typically had higher indirect tensile failure strains (>0.9%) which may be useful as an independent criteria.

9. The commonly used wet-dry indirect tensile strength ratio appears to be satisfactory for evaluating moisture damage potential of SMA mixtures. Nine of the eleven SMA mixtures duplicated from field projects had TSR's greater than 80 percent. The other two mixtures had TSR's greater than 70 percent. For the no-freeze conditioning procedure as used in this study, the 80 percent criteria should assure good protection against moisture damage.

10. Comparisons of test results between SMA mixtures containing typical Florida aggregates and SMA mixtures from field projects across the U.S. generally show that the mixtures with typical Florida materials have comparable or superior properties with respect to rutting resistance, fatigue cracking potential, and thermal cracking potential. Although some of the experimental Florida mixtures in this study had poor resistance to moisture damage, they could easily be improved by adding an antistrpping agent or by a minor increase in binder content. Therefore, SMA mixtures appear to be technically feasible in Florida.

11. Multiple linear regressions were used to identify which aggregate characteristics affected mixture properties. The most important aggregate characteristic related

to rutting resistance was DVMA from the GTM aggregate degradation test. The regressions indicate that greater rutting resistance is produced with aggregate blends that have low DVMA (high aggregate densities). Other characteristics identified to have an effect on rutting included L.A. abrasion, particle index, aggregate shear strength, and the change in percent passing the major aggregate size. Regression analyses also showed that moisture damage potential is increased for mixtures containing aggregates prone to degradation as indicated by the L.A. abrasion test or the GTM aggregate degradation test.

12. Good SMA mixtures can be produced with aggregates that do not meet the recommended specifications of the SMA Technical Working Group. Mix design tests which can be related to pavement performance are the best indicators of which aggregates and blends can be used most effectively.

13. The cost per ton for SMA mixtures is expected to be about $46 when bid competitively. For the cases where the SMA replaces equivalent thickness of Type S mixture plus an open-graded friction course, this in-place cost for SMA is competitive with the conventional construction. In the other case where the SMA serves only as the structural layer, the life of the SMA pavement would have to be only 20 months longer than conventional pavements to recover the higher initial cost of the SMA mixture.

14. SMA mixtures are intended for high volume, heavy traffic highways. Even if the implementation of the SMA technology progresses well, it will only account for a very small percentage of the hot mix asphalt placed on the state's highway system

in the next five years. Therefore, utilization of SMA in Florida is not expected to have a major effect on the hot mix industry or the aggregate industry.

15. The recommended gradation range for SMA mixtures is so narrow that only a small number of the current coarse aggregate products marketed in the state appear to fit within the usable range. However, in view of the limited application for SMA mixtures over the next several years, these few available sources should be able to cover the demand for the narrow sized aggregate.

11.2 Recommendations

The following recommendations are intended to provide necessary preliminary guidelines for the Florida Department of Transportation to specify materials, mixture design procedures, and construction operations which will result in a successful SMA pavement. Many of these recommendations are based on findings from this research study. Other pertinent information which is outside the scope of this study, such as roller selection and operation, has been taken from reports and articles from other states which have previously constructed SMA projects. An effort has been made to clearly identify the basis and or sources of the recommendations.

11.2.1 Aggregates

The selection of coarse aggregates is one of the most important choices in the implementation of the SMA technology. Generally, most states have followed the TWG guidelines for coarse aggregates. However, a number of states have utilized some

aggregates with higher abrasion values or used relatively pure carbonate materials without any apparent detrimental effects.

This research has shown that some of the softer Florida limestones tend to degrade or break down more than aggregates utilized in SMA mixtures in other states. Mixture tests with these aggregates showed that the use of the softer aggregate is not necessarily detrimental to rutting. Other aggregate characteristics such as aggregate blend density, gradation, particle shape, and surface texture may be more important to the development of a strong aggregate structure. However, aggregate degradation may lead to moisture damage, premature ravelling, a loss of skid resistance, and or a loss of shear strength during the life of the SMA pavement.

It is therefore recommended that the FDOT construct and evaluate a set of field test sections to further evaluate different aggregates in SMA mixtures and determine their performance under field conditions. The field trial should assess degradation, skid resistance and rutting resistance of mixtures containing aggregates from various sources including as many of the study materials as practical.

At the present time, it is advised that the FDOT utilize its current coarse aggregate specifications with the following additional requirements for materials to be used in SMA mixtures.

Flat & Elongated Particles (ASTM D 4791)	*10% max 3:1 ratio*
Particle Index, 9.5 mm to 4.75 mm (ASTM D 3398)	*10 min*
% Fractured Faces	*100 % 1 Face*

A fractured face should be considered as a broken surface which is greater than 20 percent of the particle surface area. No limitations are recommended for sulfate soundness, durability index, or absorption. If it is desired that the SMA be the pavement wearing surface, the FDOT's current specifications for open-graded friction course aggregates should be sufficient to assure good skid resistance.

Contingent upon the results of the field trial, further restrictions may be appropriate. For example, to minimize the potential for crushed aggregate on the pavement surface it may be necessary to lower the maximum LA abrasion loss, or utilize the gyratory aggregate degradation test and limit the change in the percent passing the major aggregate fraction and or change in the surface area. Otherwise, the recommended mix design tests should screen out materials that are not able to produce good SMA mixtures.

11.2.3 Mineral Filler

Type of mineral filler was not evaluated as part of this research project. However, this is probably a very important variable affecting SMA performance and cost. Mineral filler contents in the SMA mixtures placed in the U.S. have typically ranged between 8 and 12 percent of the total aggregate weight. A variety of materials have been used as mineral filler including agricultural lime, rock dust, portland cement, fly ash, and baghouse fines. No information has been published which indicates successes or difficulties associated with any of these materials. The potential for using baghouse fines as mineral filler in SMA

mixtures could be very beneficial in Florida by consuming this material which is generally in excess from the production of DGAC mixtures.

Common sense guidelines for mineral fillers have been given by the TWG. Fillers should be free from organic impurities and have a plasticity index not greater than 4. It is also recommended that commercial mineral fillers contain less than 20 percent by weight of particles less than 20 μm. These guidelines should be added to Section 917 of the FDOT's standard specifications for mineral fillers to be used in SMA mixtures. For more information on mineral fillers for SMA mixtures, a recent paper by Harris and Stuart [59] presents research on mineral filler characterization and their effects on SMA mixture properties.

11.2.3 Asphalt Cement

Reports from other states indicate that the grade of asphalt cement used in SMA mixtures is the same grade typically used for conventional mixtures. It is therefore recommended that the Department utilize its standard AC-30 specifications for SMA mixtures.

11.2.4 Stabilizing Additives

According to a summary provided by the FHWA [60], the most popular stabilizing additives for SMA mixtures in the U.S. are Vestoplast and cellulose fibers from a variety of suppliers. Polymers are also gaining popularity. Mineral fibers continue to be used by a few states such as Georgia. The choice of which stabilizing additive to use appears to be

based on three factors: the effect on optimum asphalt content, cost, and how to add the additive at the plant.

Based on the success of using ground tire rubber (GTR) for binder stabilization in open-graded friction mixtures in Florida, GTR would likely be the best choice for SMA mixtures as well. Tests in the FDOT's Bituminous Research Laboratory have shown that GTR is one of the most effective additives for mitigating drain-down and improving mixture tensile properties (see Appendix D). Research conducted by the Tia et al. [61] has also demonstrated that GTR improves resistance of the binder to aging.

It is therefore recommended that the FDOT utilize asphalt-rubber binder (ARB-12) as currently specified as the stabilized binder for SMA mixtures. Use of this material will not only provide technical benefits, it will also provide for easier implementation of SMA mixtures by including a familiar material.

11.3 Mix Design

Since asphalt mix designs are the responsibility of the contractor in Florida, the 50-blow Marshall procedure, as recommended by the TWG and in current use for dense-graded asphalt mixtures, should be used by contractors to develop preliminary mix designs for SMA mixtures. However, it is recommended that the Department hold the right to disapprove an SMA mix design based on results of tests for which the contractor may not be able to perform. As further assurance that the SMA mix design will perform well, the following outline of tests should be performed on the preliminary design submitted by the contractor.

1. *Compact in the GTM 9 samples to 12 gyrations as described in section 5.2.1.*

2. *Measure the maximum theoretical specific gravity of mixture using duplicate samples.*

3. *Extrude 6 of the compacted samples, determine G_{mb} ,calculate air void contents.*

4. *Determine indirect tensile strength and failure strain of three of the compacted samples as described in section 5.2.5.*

5. *Saturate the other three compacted samples to between 55 and 80 percent then condition the samples in a 60 °C water bath as described in section 5.2.8. Determine the tensile strength and failure strain of the conditioned samples as described in section 5.2.5*

6. *Perform the GTM densification/shear test on the three samples left in the molds as described in section 5.2.2.*

7. *Perform one of the following additional rutting tests to confirm rutting resistance:*
   - 7.a. *Test three beams of the SMA design in the Georgia Loaded Wheel Tester in accordance with the new GLWT procedure.*
   - 7.b. *Compact three additional samples in the GTM and test in the triaxial repeated load test as described in section 5.2.4.*

8. *Perform the NCAT draindown procedure on duplicate samples in accordance with the procedure included in reference 20.*

9. *The following criteria are recommended for SMA mixtures:*

Average air voids	*6.0 - 8.0%*
Average unconditioned tensile strength	*100 psi, min*
Average unconditioned failure strain	*0.9 %, min.*
Average gyratory shear strength, τG_{200}	*54 psi, min*
Average weight loss	*1 %, max.*
Tensile strength ratio	*80 %, min.*
GLWT rut depth at 8000 cycles	*0.15 in., max.*

Triaxial repeated-load test, strain rate, ϵ'_p	*3.61 E-5/cycle*
Average draindown	*0.3 % max.*

11.4 SMA Production

In general, conventional mixture production and placement guidelines and techniques which are considered to be good construction practices should apply to SMA mixtures as well. Therefore, SMA construction should follow the FDOT's standard specifications for asphalt mixture production, placement, testing and acceptance, with the following suggested minor modifications and guidelines.

11.4.1 Mixture Production

There are a few details regarding plant set-up and operation that may be different for SMA production. First, the type of plant and the size of the drum will affect the amount of aggregate degradation that occurs during production. Since the aggregate blend is dominated by one or two coarse aggregate components, accurate calibration of the cold feeds is important. If one aggregate component comprises a high percentage of the blend, it may be beneficial to use two cold bins for that one component for better control and to reduce variations from loading and stockpiling. Accurate and consistent feed of the mineral filler is also very important. On most of the SMA projects in the U.S., the SMA production rates have been governed by the ability to deliver consistent rates of mineral filler into the mixing operation. A calibrated mineral filler feed system, separate from the dust collection and return, is recommended.

If stabilizers other than ground tire rubber are used, a feed system must also be used to accurately and consistently deliver the stabilizer to the mixture. Fiber stabilizers also will require longer mixing times.

11.4.2 Control of Mixture Gradation

The FDOT's standard pay table for variation in gradation and binder content should be used for SMA mixtures except that tighter control should be kept on the percentage passing the No.4 sieve. Research by the National Center for Asphalt Technology has shown that this percentage substantially affects SMA mixture properties. The TWG has recommended an allowable variation of 3 percent passing the No.4 sieve from the Job Mix Formula (JMF), which seems too tight. Current FDOT specifications allow up to 7 percent variation for a single test result from the JMF. A tolerance of ± 5 percent for one test seems reasonable. Average accumulated deviations for subsequent samples in the lot should be appropriately reduced.

If ground tire rubber is used as the stabilizer, the automated printer system will be used for acceptance of binder content. This system should also be used for other polymer stabilizers such as Vestoplast and Novophalt since these additives caused some problems with the extraction test. In some cases, these additives caused the solvent to gel on the filter pad which stopped the filtration and prevented completion of the test. In these situations, even an accurate gradation could not be determined.

11.4.3 Mixture Storage

Due to the potential for draindown in SMA mixtures it is recommended that maximum time for temporary hot storage of the mixtures in surge or storage bins be limited to one hour as currently required for open-graded friction course mixtures.

11.5 SMA Placement

11.5.1 Paving Operations

Good paving practices are important to achieve a satisfactory SMA pavement. The speed of the paver should be set so that the rollers are able to stay close. Hand work and throw-backs should be kept to a minimum as with placement of open-graded friction courses. SMA mixtures usually have less roll-down than dense-graded mixtures [62,63]. Twenty-five percent is commonly used as the roll down factor for DGAC. Therefore, for SMA pavements, the screed should be set to yield a mat about 1.65 to 1.75 inches behind the screed for a 1.5 inch compacted lift.

11.5.2 Compaction

Most SMA pavements have been satisfactorily compacted with heavy, static steel-wheel rollers. Two or three rollers weighing at least 10 tons usually are capable of achieving the desired density. Vibratory rollers have been used on a few SMA projects, but are not recommended in Florida due to the potential for fracturing aggregates. Pneumatic tired rollers are also not recommended since these rollers tend to pick up and track the mastic.

Temperature of the mat has been reported to be more critical for SMA compaction [49,51,62]. Breakdown rollers should be kept close to the paving machine. Use of wide rollers was recommended by one state to reduce the number of passes necessary to cover the lane and permit the roller to keep up with the paver [51]. Intermediate and/or finish rolling should follow as closely as possible behind the breakdown rolling. The FDOT's standard density requirements should be used for SMA pavements.

11.5.3 Trial Production and Placement

Many agencies who have constructed SMA pavements have recommended the production and placement of a trial section of SMA mixture (about 500 feet) off-site to become familiar with plant process control and compaction procedures prior to construction of the project or experimental SMA test section. SMA mixtures are very different in appearance and handling from conventional dense-graded mixtures, and the construction of SMA trials will help work out any difficulties and or fears before the actual production begins.

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APPENDIX A
MIX DESIGN INFORMATION FOR FIELD MIXTURES

Mix I.D.: GA1		State: Georgia	
Date Placed: July 31, 1991		Location: I-85, Barrow, Jackson, & Banks Co.s	
Contacts: Donald Watson, Harry McGaughey, Chris Brunais (GDOT)			
Materials	Percent	Source	
1. # 6 stone	51%	Blue Circle, Buford GA	
2. # 7 stone	20%	Blue Circle, Buford GA	
3. # 89 stone	9%	Blue Circle, Buford GA	
4. W10 screenings	8%	Blue Circle, Buford GA	
5. R04 mineral filler	11%	Georgia Marble Co., Marble Hill, GA	
6. Hydrated Lime	1%	Blue Circle, Birmingham, AL	
7. AC- 30	5.8%	AMOCO, Doraville, Gwinett County	
8. Novaphalt	5% bwb	Novaphalt America	
9. Inorphil	8% bwb	Fiberand Corp.	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	62	64	85 - 95
3/8" (9.5mm)	42	39	60 - 75
# 8 (2.36mm)	20	22	20 - 28
# 50 (300μm)	16	18	12 -15
# 200 (75μm)	10	10	8 -10
Binder Content (%)	5.8	5.68	6.0 min.
Mix Design Data	Marshall Design	In-Place	
M.T.S.G.	2.422	2.437	
Air Voids (%)	4.0	5.2%	3.0 -4.0
VMA (%)	17.5		17 min

Mix I.D.: GA2		State: Georgia	
Date Placed: September 3, 1991		Location: I-85, Barrow, Jackson & Banks Co.s	
Contacts: Donald Watson, Harry McGaughey, Chris Brunais (GDOT)			
Materials	Percent	Source	
1. # 7 stone	47%	Blue Circle, Buford GA	
2. # 89 stone	29%	Blue Circle, Buford GA	
3. W10 screenings	12%	Blue Circle, Buford GA	
4. R04 mineral filler	11%	Georgia Marble Co., Marble Hill, GA	
5. Hydrated Lime	1%	Blue Circle, Birmingham AL	
6. AC-30	5.9%	AMOCO, Doraville, Gwinett County	
7. Novaphalt	5% bwb	Novaphalt America	
8. Inorphil	8% bwb	Fiberand Corp.	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	100	99	85 - 95
3/8" (9.5mm)	78	85	60 - 75
# 4 (4.75mm)	36	45	20 - 28
# 8 (2.36mm)	23	29	16 - 24
# 30 (600μm)	17		12 - 16
# 50 (300μm)	15	19	12 - 15
# 100 (150μm)	13		
# 200 (75μm)	10	10	8 - 10
Binder Content (%)	5.9	5.53	6.0 min.
Mix Design Data	Marshall Design	In-Place	
M.T.S.G.	2.425	2.451	
Air Voids (%)	3.0	7.0	3.0-4.0
VMA (%)	16.5		17 min.

Mix I.D.: GA3		State: Georgia	
Date Placed: September 17, 1991		Location: I-85, Barrow, Jackson & Banks Co.s	
Contacts: Donald Watson, Harry McGaughey, Chris Brunais (GDOT)			
Materials	Percent	Source	
1. # 7 stone	35%	Martin Marietta, Ruby Quarry, Gray GA	
2. # 89 stone	39%	Martin Marietta, Ruby Quarry, Gray GA	
3. Screenings	15%	Martin Marietta, Ruby Quarry, Gray GA	
4. R04 mineral filler	10%	Georgia Marble Co., Marble Hill, GA	
5. Hydrated Lime	1%	Blue Circle, Birmingham, AL	
6. AC-30	6.3%	AMOCO, Doraville, Gwinett Co. GA	
7. Novaphalt	5% by wt. binder	Novapahlt America	
8. Inorphil	8% by wt. binder	Fiberand Corp.	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	100	99	85 - 95
3/8" (9.5mm)	81	83	60 - 75
# 4 (4.75mm)	37	38	20 - 28
# 8 (2.36mm)	23	24	16 - 24
# 30 (600μm)	16		12 - 16
# 50 (300μm)	14	16	12 - 15
# 100 (150μm)	12		
# 200 (75μm)	10	10	8 - 10
Binder Content (%)	6.3	5.64	6.0 min.
Mix Design Data	Marshall Design	In-Place	
M.T.S.G.	2.468	2.491	
Air Voids (%)	3.4	6.3	3.0-4.0
VMA(%)	18.0		17 min.

Mix I.D.: GA4		State:Georgia	
Date Placed: October 21 & 22, 1992		Location: I-75, Henry County	
Contacts: Donald Watson, Harry McGaughey, Chris Brunais (GDOT)			
Materials	Percent	Source	
1. #7 Stone	46%	Florida Rock Ind., Mt. View, GA	
2. #89 Stone	30%	Florida Rock Ind., Mt. View, GA	
3. #777 Stone	15%	Florida Rock Ind., Tyrone, GA	
4. R04 mineral filler	8%	Georgia Marble Co., Marble Hill, GA	
5. Hydrated Lime	1%	Cheney Lime, Allgood, AL	
6. AC-20 Special		Shell, Fulco Facility, Fulton Co., GA	
7. Styrelf (SBS)	3% bwb	Elf Asphalt, Inc.	
8. Cellulose Fiber	0.3% total mix	Custom Fibers International	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	100	99	85 - 95
3/8" (9.5mm)	80	79	60 - 75
# 4 (4.75mm)	37	39	20 - 28
# 8 (2.36mm)	25	25	16 - 24
# 30 (600μm)			12 - 16
# 50 (300μm)	12	15	12 - 15
# 200 (75μm)	8	8	8 - 10
Binder Content (%)	5.8	5.93	6.0 min.
Mix Design	Marshall	In-Place	
M.T.S.G.	2.442	2.464	
Air Voids (%)	3.8	5.7	3.0-4.0
VMA (%)	17.1		17 min.

Mix I.D.: WI1		State: Wisconsin	
Date Placed: July 1991		Location: I-94, Waukesha County	
Contacts: Bob Schmiedlin (WDOT), Jack Weigel (Payne & Dolan, Inc.)			
Materials	Percent	Source	
1. ½" Chip	33%	W.L.S. East Quarry	
2. ⅜" Chip	35%	W.L.S. East Quarry	
3. ¼" Screenings	25%	W.L.S. East Quarry	
4. Superfine (90/99)	7%	W.L.S. Dust Plant	
5. 85-100 AC	6.5%	AMOCO	
6. Vestoplast	7% bwb		
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	93.8	94	85 - 95
3/8" (9.5mm)	69.6	69	60 - 75
# 4 (4.75mm)	27.9	28	20 - 28
# 8 (2.36mm)	20.1	20	16 - 24
# 16 (1.18mm)	16.3	16	
# 30 (600μm)	14.2	14	12 - 16
# 50 (300μm)	13.2	13	12 - 15
# 100 (150μm)	12.4	12	
# 200 (75μm)	10.8	10	8 - 10
Binder Content (%)	6.5%	5.5	6.0 min.
Mix Design	Marshall, beveled ft.	In Place	
M.T.S.G.	2.558		
Air Voids (%)	3.1	6.8	3.0-4.0
VMA (%)	16.4		17 min.

Mix I.D.: WI2		State: Wisconsin	
Date Placed: August 1992		Location: I-43, Waukesha County	
Contacts: Bob Schmiedlin (WDOT), Jack Weigel (Payne & Dolan, Inc.)			
Materials	Percent	Source	
1. ⅜" Chip	45%	Crowbar	
2. ¼" Chip	33%	Crowbar	
3. Mfg'd. Sand	12%	Crowbar	
4. Superfine (90/99)	10%	W.L.S. Dust Plant	
5. 85-100 AC	7.0%	AMOCO	
6. Vestoplast	7% bwb		
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	100	100	85 - 95
3/8" (9.5mm)	97.7	96.3	60 - 75
# 4 (4.75mm)	34.8	35.8	20 - 28
# 8 (2.36mm)	20.7	21.9	16 - 24
# 16 (1.18mm)	16.5	17.7	
# 30 (600μm)	14.2	15.7	12 - 16
# 50 (300μm)	12.8	14.6	12 - 15
# 100 (150μm)	11.7	14	
# 200 (75μm)	10.8	12.3	8 - 10
Binder Content (%)	7.0%	5.5	6.0 min.
Mix Design	Marshall, beveled ft.	In Place	
M.T.S.G.	2.473	2.507	
Air Voids (%)	3.1	10.5	3.0-4.0
VMA (%)	17.7		17 min.

Mix I.D.: WI3		State: Wisconsin	
Date Placed: September 1993		Location: Ryan Road, Milwaukee	
Contacts: Jack Weigel (Payne & Dolan, Inc.)			
Materials	Percent	Source	
1. ⅜" Chip	65%	Franklin, Milwaukee County	
2. ¼" Chip	15%	Franklin, Milwaukee County	
3. Mfg'd. Sand	10%	Franklin, Milwaukee County	
4. Superfine (90/99)	10%	W.L.S. Dust Plant	
5. MAC 10	6.2%	Seneca Petroleum Co.	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	100	100	85 - 95
3/8" (9.5mm)	96.6	96	60 - 75
# 4 (4.75mm)	36.0	36	20 - 28
# 8 (2.36mm)	23.5	24	16 - 24
# 16 (1.18mm)	18.6	19	
# 30 (600μm)	15.9	17	12 - 16
# 50 (300μm)	14.5	16	12 - 15
# 100 (150μm)	13.6	15	
# 200 (75μm)	12.1	12.9	8 - 10
Binder Content (%)	6.2%	6.2	6.0 min.
Mix Design	Marshall, beveled ft.	In Place	
M.T.S.G.	2.482	2.507	
Air Voids (%)	3.0	7.6	3.0-4.0
VMA (%)	15.1		17 min.

Mix I.D.: WI4		State: Wisconsin	
Date Placed: September 1993		Location: US-45, Three Lakes	
Contacts: Bob Schmiedlin (WDOT), Jack Weigel (Payne & Dolan, Inc.)			
Materials	Percent	Source	
1. 5/8" Chip	45%	Consolidated, Oneida County	
2. 7/16" Chip	33%	Consolidated, Oneida County	
3. Mfg'd. Sand	12%	Consolidated, Oneida County	
4. Superfine (90/99)	10%	W.L.S. Dust Plant	
5. 85-100 AC	6.0%	Murphy	
6. Inorganic Fibers	0.5% total mix		
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	99.9	100	100
1/2" (12.5mm)	90.1	91	85 - 95
3/8" (9.5mm)	70.4	77	60 - 75
# 4 (4.75mm)	24.7	26	20 - 28
# 8 (2.36mm)	20.6	19	16 - 24
# 16 (1.18mm)	17.6	16	
# 30 (600μm)	15.6	15	12 - 16
# 50 (300μm)	13.3	12	12 - 15
# 100 (150μm)	11.1	10	
# 200 (75μm)	9.6	9.2	8 - 10
Binder Content (%)	6.0%	5.9	6.0 min.
Mix Design	Marshall, beveled ft.	In Place	
M.T.S.G.	2.535	2.541	
Air Voids (%)	2.9	6.5	3.0-4.0
VMA (%)	15.2		17 min.

Mix I.D.: VA1		State: Virginia	
Date Placed: Fall 1992		Location: US 29, Lynchburg	
Contacts: Robert Wilson, Dale Grigg (VDOT)			
Materials	Percent	Source	
1. ¾" x ⅜"	60%	W.W. Boxley Inc., Piney River	
2. ⅜" x #4	23%	W.W. Boxley Inc., Piney River	
3. Agricultural Lime	16%	W.W. Boxley Inc., Lawyers Rd.	
4. Hydrated Lime	1%	APG, Ripplemead	
5. AC-20	6.5%	Exxon, Richmond	
6. Cellulose Fibers	0.3% total mix	Scan Road, Waco Texas	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	90.3	85	85 - 95
3/8" (9.5mm)	66.6	63	60 - 75
# 4 (4.75mm)	27.8	28	20 - 28
# 8 (2.36mm)	19.2	20	16 - 24
# 16 (1.18mm)			
# 30 (600μm)	16.1	17	12 - 16
# 50 (300μm)	14.7	16	12 - 15
# 100 (150μm)	12.7	15	
# 200 (75μm)	10.6	12	8 - 10
Binder Content (%)	6.5%	6.2	6.0 min.
Mix Design	Marshall	In Place	
M.T.S.G.	2.472	2.470	
Air Voids (%)	4.5	7.3	3.0-4.0
VMA (%)	18.3		17 min.

Mix I.D.: MD1		State: Maryland	
Date Placed: June 1992		Location: US 15, Frederick	
Contacts: Bill Wells, Larry Michaels (MDDOT)			
Materials	Percent	Source	
1. #68 stone	43%	Virginia Trap Rock, Leesburg, VA	
2. #8 stone	35%	Virginia Trap Rock, Leesburg, VA	
3. Birdeye	11%	Genstar Stone Products, Frederick, MD	
4. Agricultural Lime	11%	Genstar Stone Products, Texas, MD	
5. AC-20	6.0%	Chevron Asphalt, Baltimore	
6. Vestoplast	7% by wt.binder		
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
3/4" (19mm)	100	100	100
1/2" (12.5mm)	84	89	85 - 95
3/8" (9.5mm)	68	71	60 - 75
# 4 (4.75mm)	28	31	20 - 28
# 8 (2.36mm)	15	18	16 - 24
# 16 (1.18mm)	13	15	
# 30 (600μm)	12	14	12 - 16
# 50 (300μm)	12	13	12 - 15
# 100 (150μm)	11	12	
# 200 (75μm)	9.2	9.6	8 - 10
Binder Content (%)	6.0%	6.2	6.0 min.
Mix Design	Marshall	In Place	
M.T.S.G.	2.626	2.626	
Air Voids (%)	4.2	7.3	3.0-4.0
VMA (%)	18.9		17 min.

Mix I.D.: TX1		State: Texas	
Date Placed: August 1992		Location: I-35 Bus. Loop, Alvarado	
Contacts: Maghsoud Tahmoressi, David Bass (TXDOT)			
Materials	Percent	Source	
1. Grade 3	30%	Pioneer, W'ford	
2. Type D	43%	Pioneer, W'ford	
3. Grade 4	14%	Pioneer, W'ford	
4. Mineral Filler	13%	Texas Lime, Cleburne	
5. AC-20	6.0%	Fina, Big Springs	
6. Anti-strip	0.5% by wt.binder	Perma Tac Plus	
7. Cellulose Fiber	0.3% total mixture	Arbocel, Scan Road, Waco	
Job Mix Formula			
Sieve	Design	Produced	TWG Specification
5/8" (16mm)	100	99.5	100
1/2" (12.5mm)	91.7	89.3	85 - 95
3/8" (9.5mm)	69.2	65.4	60 - 75
# 4 (4.75mm)	28.3	28.5	20 - 28
# 10 (2.00mm)	15.2	15.4	
# 40 (425μm)	13.5	13.9	
# 80 (180μm)	13.2	13.3	
# 200 (75μm)	10.9	10.1	8 - 10
Binder Content (%)	6.0%	6.4	6.0 min.
Mix Design	Marshall	In Place	
M.T.S.G.	2.423	2.458	
Air Voids (%)	4.0	7.0	3.0-4.0
VMA (%)			17 min.

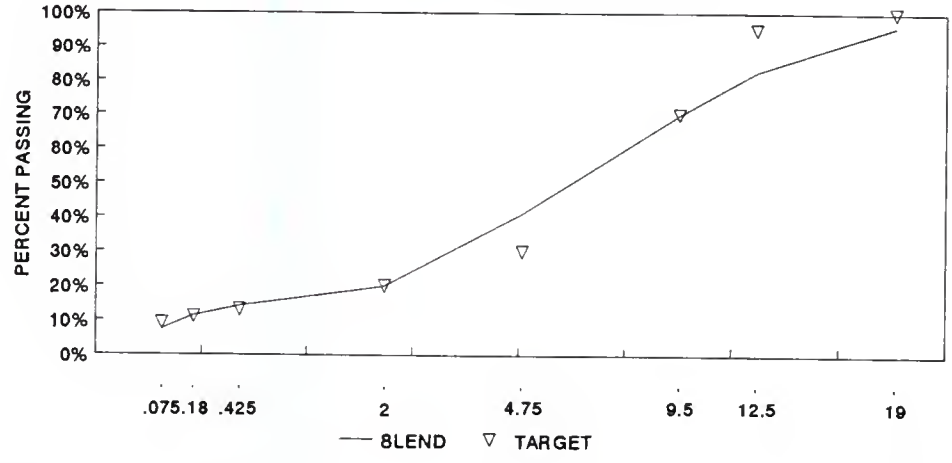
APPENDIX B
BATCH SHEETS FOR EXPERIMENTAL FLORIDA MIXTURES

WHITEROCK SMA (FL1)

BLENDING

DESC.	S-1A	S-1B	SCRN	RO4		
% IN BLEND	0.33	0.47	0.1	0.1	1	
SIEVES	AGG.1	AGG.2	AGG.3	AGG.4	BLEND	TARGET
3/4	87.8%	100.0%	100.0%	100.0%	96.0%	100%
1/2	47.1%	100.0%	100.0%	100.0%	82.5%	95%
3/8	10.9%	98.4%	100.0%	100.0%	69.8%	70%
#4	0.8%	44.6%	99.9%	100.0%	41.2%	30%
#10	0.7%	3.5%	81.2%	100.0%	20.0%	20%
#40	0.7%	0.4%	37.3%	100.0%	14.1%	13%
#80	0.6%	0.3%	14.2%	95.0%	11.3%	11%
#200	0.50%	0.3%	1.50%	71.20%	7.6%	9%

GRADATION ANALYSIS



WHITEROCK SMA (FL1) BATCHING TOTAL AGGREGATE WEIGHT 1050 g

DESC.	S-1A		S-1B		SCR		RO4				
% IN BLEND	0.33		0.47		0.1		0.1				
SIEVES	AGG.1		AGG.2		AGG.3		AGG.4		SUM	TARGET	ADJUSTED
3/4	42.3		0.0		0.0		0.0		42.3	0.0	0
1/2	141.0	52.5	0.0		0.0		0.0		141.0	52.5	52.5
3/8	125.4	255	7.9	7.5	0.0		0.0		133.3	262.5	262.5
#4	35.0	80	265.5	340	0.1		0.0		300.6	420.0	420
#10	0.3	0	202.8	100	19.6	5	0.0		222.8	105.0	105
#40	0.0	0	15.3	23	46.1	50.5	0.0		61.4	73.5	73.5
#80	0.3	0	0.5	0	24.3	16	5.3	5.3	30.3	21.0	21.3
#200	0.3	0	0.0	0	13.3	0	25.0	25	38.7	21.0	25
-200	1.7	7	1.5	6	1.6	6	74.8	75	79.5	94.5	94
							TOTAL		1050		1053.8

BATCH SHEET: ALL SIEVES

WHITEROCK SMA (FL1) CUMULATIVE WEIGHTS

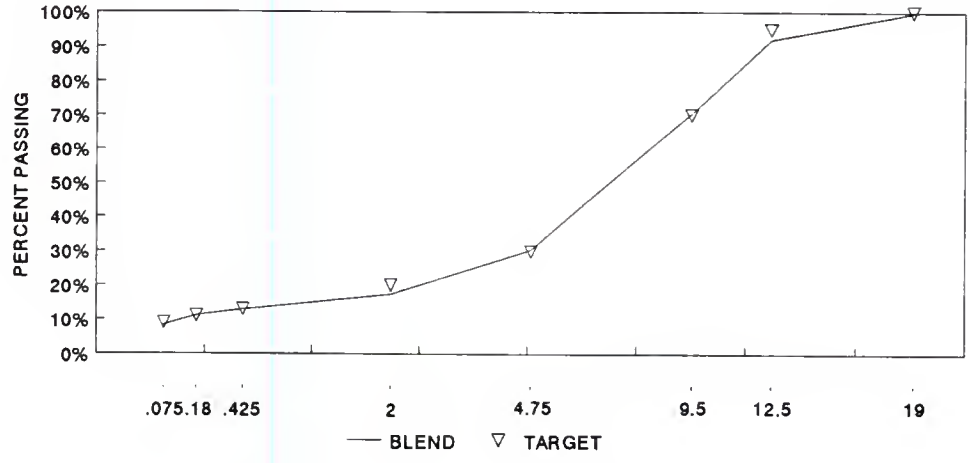
DESC.	S-1A	S-1B	SCR	RO4
SIEVES				
3/4	0.0	0.0	0.0	0.0
1/2	52.5	52.5	52.5	52.5
3/8	307.5	315.0	315.0	315.0
#4	395.0	735.0	735.0	735.0
#10	735.0	835.0	840.0	840.0
#40	840.0	863.0	913.5	913.5
#80	913.5	913.5	929.5	934.8
#200	934.8	934.8	934.8	959.8
-200	966.8	972.8	978.8	1053.8

SFA (FL2)

BLENDING

DESC.	#67	S-1B	SCRN	RO4		
% IN BLEND	0.4	0.4	0.095	0.105	1	
SIEVES	AGG.1	AGG.2	AGG.3	AGG.4	BLEND	TARGET
3/4	99.5%	100.0%	100.0%	100.0%	99.8%	100%
1/2	80.0%	100.0%	100.0%	100.0%	92.0%	95%
3/8	29.1%	97.1%	100.0%	100.0%	70.5%	70%
#4	2.4%	25.3%	93.9%	100.0%	30.5%	30%
#10	1.5%	1.2%	61.3%	100.0%	17.4%	20%
#40	1.0%	0.8%	17.0%	100.0%	12.8%	13%
#80	1.0%	0.5%	6.8%	95.0%	11.2%	11%
#200	0.40%	0.5%	4.60%	71.20%	8.3%	9%

GRADATION ANALYSIS



SFA (FL2) BATCHING TOTAL AGGREGATE WEIGHT 1050 g

DESC.	#67		S-1B		SCR		RO4				
% IN BLEND	0.4		0.4		0.095		0.105				
SIEVES	AGG.1		AGG.2		AGG.3		AGG.4		SUM	TARGET	ADJUSTED
3/4	2.1		0.0		0.0		0.0		2.1	0.0	0
1/2	81.9	52.5	0.0		0.0		0.0		81.9	52.5	52.5
3/8	213.8	255	12.2	7.5	0.0		0.0		226.0	262.5	262.5
#4	112.1	115	301.6	305	6.1		0.0		419.8	420.0	420
#10	3.8	0	101.2	100	32.5	5	0.0		137.5	105.0	105
#40	2.1	0	1.7	5	44.2	68	0.0		48.0	73.5	73
#80	0.0	0	1.3	2	10.2	13.7	5.5	5.3	16.9	21.0	21
#200	2.5	0	0.0	0	2.2	0	26.2	25	31.0	21.0	25
-200	1.7	7	2.1	6	4.6	6	78.5	75	72.5	94.5	94
								TOTAL	1035.6		1053

BATCH SHEET: ALL SIEVES

SFA (FL2) CUMULATIVE WEIGHTS

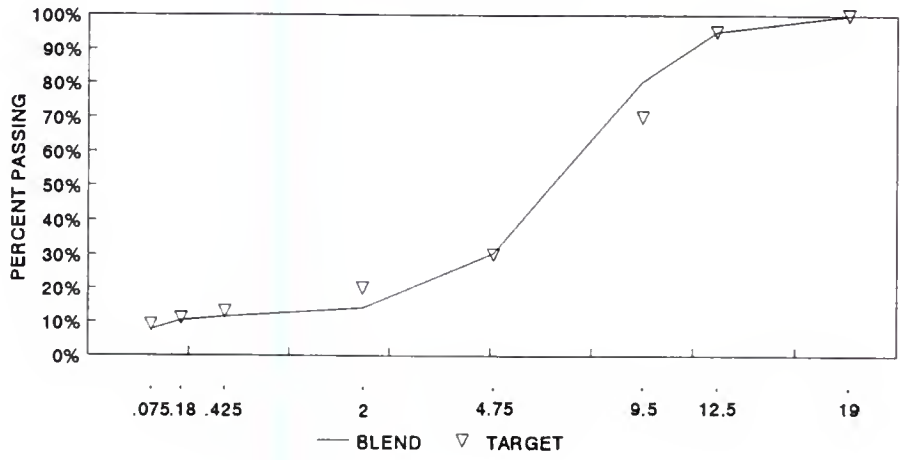
DESC.	#67	S-1B	SCR	RO4
SIEVES				
3/4	0.0	0.0	0.0	0.0
1/2	52.5	52.5	52.5	52.5
3/8	307.5	315.0	315.0	315.0
#4	430.0	735.0	735.0	735.0
#10	735.0	835.0	840.0	840.0
#40	840.0	845.0	913.0	913.0
#80	913.0	915.0	928.7	934.0
#200	934.0	934.0	934.0	959.0
-200	966.0	972.0	978.0	1053.0

SCA (FL3)

BLENDING

DESC.	#57	S-1	SCRN	RO4		
% IN BLEND	0.25	0.6	0.05	0.1	1	
SIEVES	AGG.1	AGG.2	AGG.3	AGG.4	BLEND	TARGET
3/4	99.5%	100.0%	100.0%	100.0%	99.9%	100%
1/2	80.0%	100.0%	100.0%	100.0%	95.0%	95%
3/8	29.1%	97.1%	100.0%	100.0%	80.5%	70%
#4	2.4%	25.3%	93.9%	100.0%	30.5%	30%
#10	1.5%	1.2%	61.3%	100.0%	14.2%	20%
#40	1.0%	0.8%	17.0%	100.0%	11.6%	13%
#80	1.0%	0.5%	6.8%	95.0%	10.4%	11%
#200	0.40%	0.5%	4.60%	71.20%	7.8%	9%

GRADATION ANALYSIS



BATCHING

TOTAL AGGREGATE WEIGHT 1050 g

DESC.	#57		S-1B		SCR		RO4				
% IN BLEND	0.25		0.6		0.05		0.1				
SIEVES	AGG.1		AGG.2		AGG.3		AGG.4		SUM	TARGET	ADJUSTED
3/4	1.3		0.0		0.0		0.0		1.3	0.0	0
1/2	51.2	52.5	0.0		0.0		0.0		51.2	52.5	52.5
3/8	133.6	200	18.3	62.5	0.0		0.0		151.9	262.5	262.5
#4	70.1	20	452.3	400	3.2	0	0.0		525.6	420.0	420
#10	2.4	0	151.8	100	17.1	5	0.0		171.3	105.0	105
#40	1.3	2	2.5	10	23.3	61.5	0.0		27.1	73.5	73.5
#80	0.0	1	1.9	3	5.4	12	5.3	5	12.5	21.0	21
#200	1.6	0	0.0	0	1.2	0	25.0	25	27.7	21.0	25
-200	1.1	4	3.2	6	2.4	9	74.8	75	81.4	94.5	94
								TOTAL	1050		1053.5

BATCH SHEET: ALL SIEVES
CUMULATIVE WEIGHTS

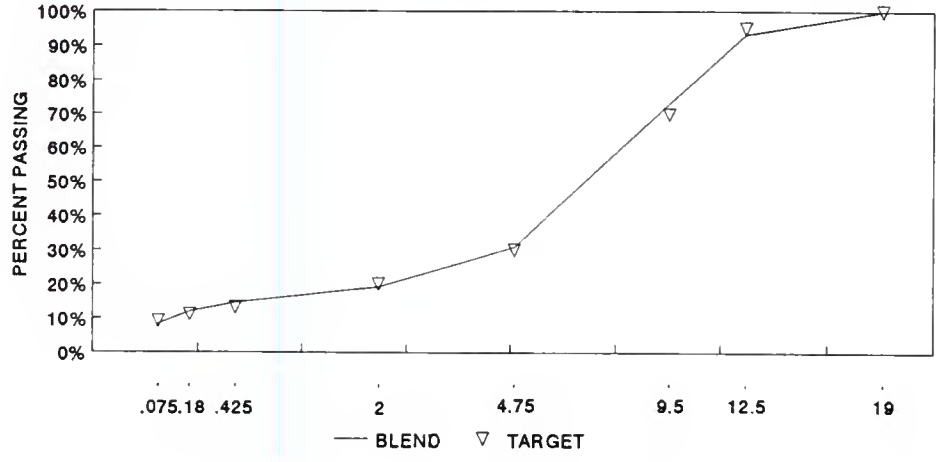
DESC.	#57	S-1B	SCR	RO4
SIEVES				
3/4	0.0	0.0	0.0	0.0
1/2	52.5	52.5	52.5	52.5
3/8	252.5	315.0	315.0	315.0
#4	335.0	735.0	735.0	735.0
#10	735.0	835.0	840.0	840.0
#40	842.0	852.0	913.5	913.5
#80	914.5	917.5	929.5	934.5
#200	934.5	934.5	934.5	959.5
-200	963.5	969.5	978.5	1053.5

CRUSHED PCC (FL4)

BLENDING

DESC.	S-1A	S-1B	SCRN	RO4		
% IN BLEND	0.37	0.45	0.08	0.1	1	
SIEVES	AGG.1	AGG.2	AGG.3	AGG.4	BLEND	TARGET
3/4	100.0%	100.0%	100.0%	100.0%	100.0%	100%
1/2	81.7%	100.0%	100.0%	100.0%	93.2%	95%
3/8	27.6%	99.9%	100.0%	100.0%	73.2%	70%
#4	4.1%	25.2%	100.0%	100.0%	30.9%	30%
#10	2.9%	4.1%	79.6%	100.0%	19.3%	20%
#40	1.0%	2.7%	36.5%	100.0%	14.5%	13%
#80	1.0%	1.6%	17.0%	95.0%	12.0%	11%
#200	0.70%	1.0%	6.00%	71.20%	8.3%	9%

GRADATION ANALYSIS



CRUSHED PCC (FL4) BATCHING TOTAL AGGREGATE WEIGHT 950 g

DESC.	S-1A		S-1B		SCR		RO4				
% IN BLEND	0.37		0.45		0.08		0.1				
SIEVES	AGG.1		AGG.2		AGG.3		AGG.4		SUM	TARGET	ADJUSTED
3/4	0.0		0.0		0.0		0.0		0.0	0.0	0
1/2	64.3	47.5	0.0		0.0		0.0		64.3	47.5	47.5
3/8	190.2	237	0.4	0.5	0.0		0.0		190.6	237.5	237.5
#4	82.6	65	319.3	315	0.0		0.0		401.9	380.0	380
#10	4.2	2.5	90.2	90	15.5	2.5	0.0		109.9	95.0	95
#40	6.7	10	6.0	12	32.8	44.5	0.0		45.4	66.5	66.5
#80	0.0	0	4.7	1.9	14.8	12	4.8	5.1	24.3	19.0	19
#200	1.1	0	2.6	0	8.4	0	22.6	24.2	34.6	19.0	24.2
-200	2.5	3	4.3	5	4.6	5	67.6	72.5	78.9	85.5	85.5
								TOTAL	950		955.2

BATCH SHEET: ALL SIEVES

CRUSHED PCC (FL4) CUMULATIVE WEIGHTS

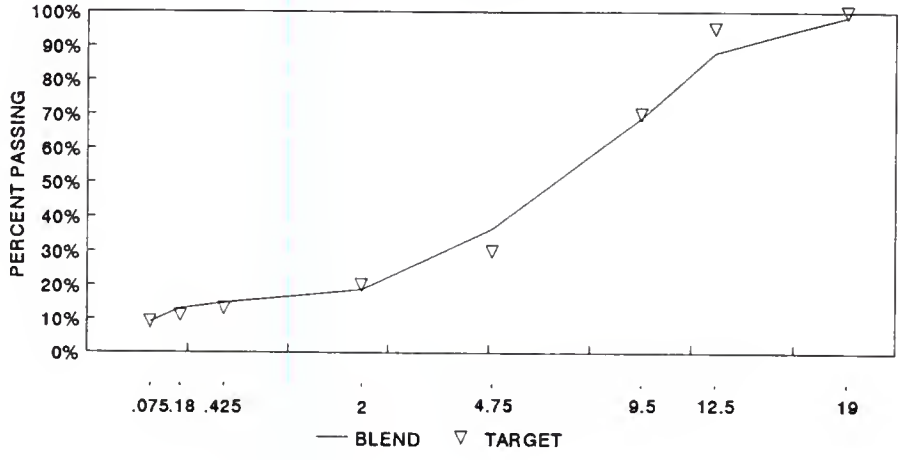
DESC.	S-1A	S-1B	SCR	RO4
SIEVES				
3/4	0.0	0.0	0.0	0.0
1/2	47.5	47.5	47.5	47.5
3/8	284.5	285.0	285.0	285.0
#4	350.0	665.0	665.0	665.0
#10	667.5	757.5	760.0	760.0
#40	770.0	782.0	826.5	826.5
#80	826.5	828.4	840.4	845.5
#200	845.5	845.5	845.5	869.7
-200	872.7	877.7	882.7	955.2

SAA (FL5)

BLENDING

DESC.	#67	S-1	SCRN	RO4		
% IN BLEND	0.48	0.31	0.1	0.11	1	
SIEVES	AGG.1	AGG.2	AGG.3	AGG.4	BLEND	TARGET
3/4	97.0%	100.0%	100.0%	100.0%	98.6%	100%
1/2	75.0%	100.0%	100.0%	100.0%	88.0%	95%
3/8	35.0%	100.0%	100.0%	100.0%	68.8%	70%
#4	4.1%	48.1%	87.0%	100.0%	36.6%	30%
#10	1.0%	3.8%	60.6%	100.0%	18.7%	20%
#40	1.0%	1.7%	27.8%	100.0%	14.8%	13%
#80	1.0%	1.0%	17.2%	95.0%	13.0%	11%
#200	0.40%	0.3%	10.10%	71.20%	9.1%	9%

GRADATION ANALYSIS



BATCHING

TOTAL AGGREGATE WEIGHT 1138 g

DESC.	#67		S-1B		SCR		RO4				
% IN BLEND	0.48		0.31		0.1		0.11				
SIEVES	AGG.1		AGG.2		AGG.3		AGG.4		SUM	TARGET	ADJUSTED
3/4	16.4		0.0		0.0		0.0		16.4	0.0	0
1/2	120.2	56.9	0.0		0.0		0.0		120.2	56.9	56.9
3/8	218.5	284.5	0.0	0	0.0		0.0		218.5	284.5	284.5
#4	168.8	185.2	183.1	250	14.8	20	0.0		366.7	455.2	455.2
#10	16.9	0	156.3	113.8	30.0	0	0.0		203.3	113.8	113.8
#40	0.0	0	7.4	24.7	37.3	55	0.0		44.7	79.7	79.7
#80	0.0	0	2.5	3.8	12.1	12.7	6.3	6.3	20.8	22.8	22.8
#200	3.3	0	2.5	0	8.1	0	29.8	23.8	43.6	22.8	23.8
-200	2.2	2	1.1	1	11.5	10	89.1	89.1	103.9	102.4	102.1
								TOTAL	1138		1138.8

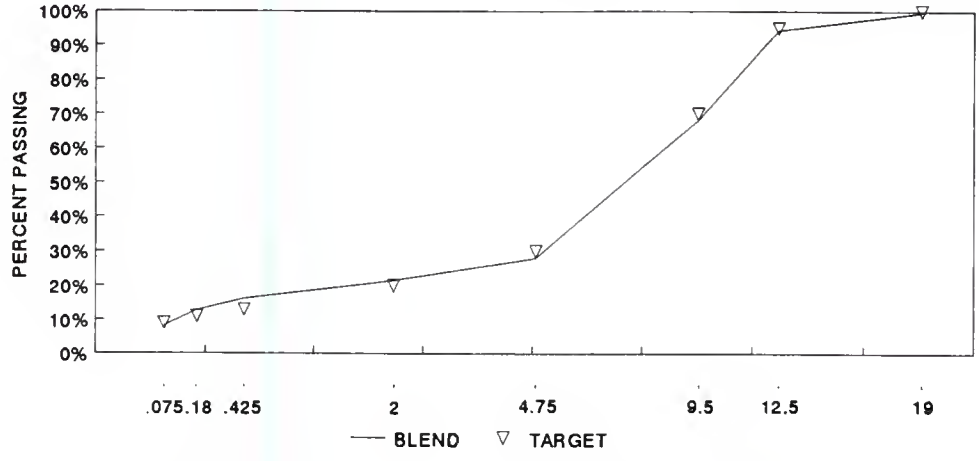
BATCH SHEET: ALL SIEVES
CUMULATIVE WEIGHTS

DESC.	#67	S-1B	SCR	RO4
SIEVES				
3/4	0.0	0.0	0.0	0.0
1/2	56.9	56.9	56.9	56.9
3/8	341.4	341.4	341.4	341.4
#4	526.6	776.6	796.6	796.6
#10	796.6	910.4	910.4	910.4
#40	910.4	935.1	990.1	990.1
#80	990.1	993.9	1006.6	1012.9
#200	1012.9	1012.9	1012.9	1036.7
-200	1038.7	1039.7	1049.7	1138.8

CHATTAHOOCHEE RIVER GRAVEL (FL6)
BLENDING

DESC.	#67	S-1B	SCRN	RO4		
% IN BLEND	0.1	0.7	0.1	0.1	1	
SIEVES	AGG.1	AGG.2	AGG.3	AGG.4	BLEND	TARGET
3/4	96.9%	100.0%	100.0%	100.0%	99.7%	100%
1/2	75.0%	95.5%	100.0%	100.0%	94.4%	95%
3/8	37.0%	63.3%	100.0%	100.0%	68.0%	70%
#4	7.0%	10.4%	100.0%	100.0%	28.0%	30%
#10	2.0%	3.8%	88.0%	100.0%	21.7%	20%
#40	1.0%	2.7%	42.7%	100.0%	16.3%	13%
#80	1.0%	2.0%	18.4%	95.0%	12.8%	11%
#200	0.50%	1.1%	3.40%	71.20%	8.3%	9%

GRADATION ANALYSIS



CHATTAHOOCHEE RIVER GRAVIBATCHING TOTAL AGGREGATE WEIGHT 1100 g

DESC.	#67		S-1B		SCR		RO4				
% IN BLEND	0.1		0.7		0.1		0.1				
SIEVES	AGG.1		AGG.2		AGG.3		AGG.4		SUM	TARGET	ADJUSTED
3/4	3.4		0.0		0.0		0.0		3.4	0.0	0
1/2	24.1	20	34.7	35	0.0		0.0		58.7	55.0	55
3/8	41.8	25	247.9	250	0.0		0.0		289.7	275.0	275
#4	33.0	33	407.3	407	0.0		0.0		440.3	440.0	440
#10	5.5	10	50.8	75	13.2	25	0.0		69.5	110.0	110
#40	1.1	2	8.5	12	49.8	63	0.0		59.4	77.0	77
#80	0.0	0	5.4	0	26.7	16.5	5.5	5.5	37.6	22.0	22
#200	0.6	0	6.9	0	16.5	0	26.2	26.2	50.2	22.0	26.2
-200	0.6	1	8.5	13	3.7	6	78.3	78.3	91.1	99.0	98.3
							TOTAL		1100		1103.5

BATCH SHEET: ALL SIEVES
CHATTAHOOCHEE RIVER GCUMULATIVE WEIGHTS

DESC.	#67	S-1B	SCR	RO4
SIEVES				
3/4	0.0	0.0	0.0	0.0
1/2	20.0	55.0	55.0	55.0
3/8	80.0	330.0	330.0	330.0
#4	363.0	770.0	770.0	770.0
#10	780.0	855.0	880.0	880.0
#40	882.0	894.0	957.0	957.0
#80	957.0	957.0	973.5	979.0
#200	979.0	979.0	979.0	1005.2
-200	1006.2	1019.2	1025.2	1103.5

APPENDIX C
GYRATORY COMPACTION AND DENSIFICATION DATA

MIX ID: BUFORD, COARSE (GA1)

GTM COMPACTION

RICE: 2.437
BSG(Agg) 2.635
BINDER % 5.7

SAMPLE SBcN57.2

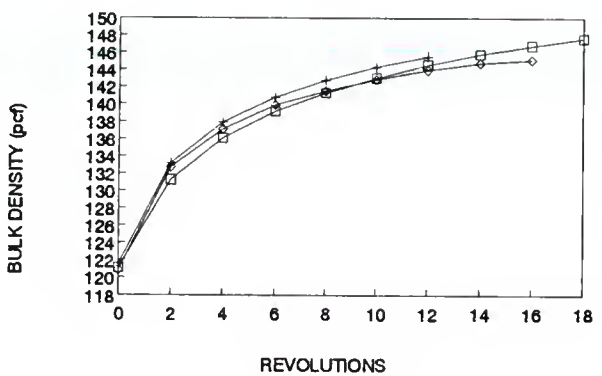
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.086	9	21.0	1.941	121.1	20.4	30.5
2	2.850	18	45.6	2.103	131.2	13.7	24.7
4	2.749	19.3	50.7	2.180	136.0	10.5	22.0
6	2.688	19.5	52.3	2.230	139.1	8.5	20.2
8	2.647	19	51.8	2.264	141.3	7.1	19.0
10	2.615	18.8	51.9	2.292	143.0	6.0	18.0
12	2.587	19	53.0	2.317	144.6	4.9	17.1
14	2.565	19.3	54.3	2.336	145.8	4.1	16.4
16	2.546	19	53.6	2.352	146.8	3.5	15.8
18	2.533	19	54.1	2.366	147.6	2.9	15.3

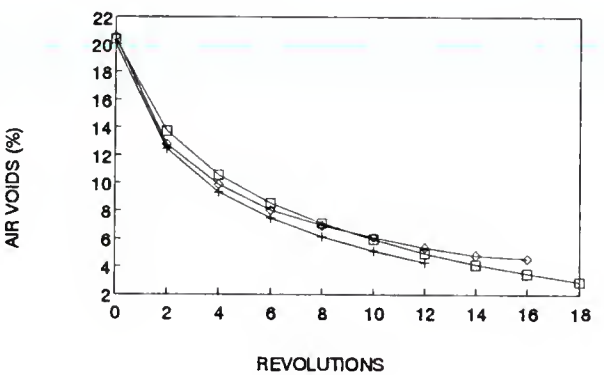
SAMPLE SBcN57.5

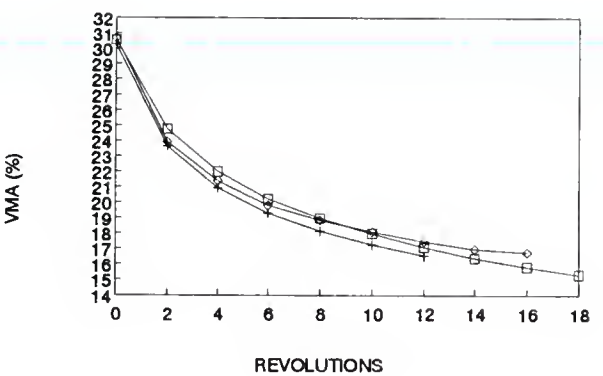
REV	HT	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.100	10	23.3	1.946	121.5	20.1	30.3
2	2.830	19.5	49.7	2.134	133.2	12.4	23.8
4	2.733	20	52.8	2.210	137.9	9.3	20.9
6	2.676	20.3	54.7	2.255	140.7	7.5	19.3
8	2.640	20.3	55.5	2.288	142.6	6.1	18.1
10	2.612	19.7	54.4	2.312	144.3	5.1	17.2
12	2.590	19	52.9	2.332	145.5	4.3	16.5
14							
16							
18							

SAMPLE SBcN57.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.096	9.7	22.8	1.937	120.9	20.5	30.7
2	2.820	19	48.6	2.126	132.7	12.7	23.9
4	2.730	20.3	53.7	2.196	137.1	9.9	21.4
6	2.675	21.5	56.0	2.242	139.9	8.0	19.6
8	2.644	22	60.0	2.268	141.5	6.9	18.6
10	2.620	22	60.6	2.269	142.8	6.1	18.1
12	2.600	22	61.1	2.306	143.9	5.4	17.5
14	2.585	22.5	62.8	2.320	144.7	4.8	17.0
16	2.576	22	61.6	2.326	145.1	4.6	16.8
18							







MIX ID: BUFORD, COARSE (GA1)

GTM COMPACTION

RICE: 2.437
BSG(Agg) 2.635
BINDER % 5.7

SAMPLE SBcN57.5

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.100	10.0	23.3	1.946	121.6	20.1	30.3
2	2.830	19.5	49.7	2.134	133.2	12.4	23.6
4	2.733	20.0	52.6	2.210	137.9	9.3	20.9
6	2.678	20.3	54.7	2.255	140.7	7.5	19.3
8	2.640	20.3	55.5	2.288	142.8	6.1	18.1
10	2.612	19.7	54.4	2.312	144.3	5.1	17.2
12	2.590	19.0	52.9	2.332	145.5	4.3	16.5

SAMPLE SBcN57.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.193	9.5	21.5	1.916	119.7	21.3	31.4
1	3.030			2.021	126.1	17.1	27.7
2	2.907			2.107	131.5	13.6	24.6
3	2.839			2.157	134.6	11.5	22.8
4	2.791			2.194	136.9	10.0	21.5
5	2.757	19.0	49.7	2.221	138.6	8.9	20.5
6	2.734			2.240	139.8	8.1	19.6
7	2.710			2.260	141.0	7.3	19.1
8	2.689			2.277	142.1	6.6	18.5
9	2.670			2.294	143.1	5.9	17.9
10	2.654	19.0	51.7	2.307	144.0	5.3	17.4
11	2.638			2.321	144.9	4.7	16.9
12	2.626	19.0	52.2	2.332	145.5	4.3	16.5

SAMPLE SBcN57.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.190	10.0	22.6	1.912	119.3	21.5	31.6
1	3.029			2.014	125.7	17.4	27.9
2	2.905			2.100	131.0	13.8	24.9
3	2.835			2.152	134.3	11.7	23.0
4	2.785			2.190	136.7	10.1	21.6
5	2.750	20.0	52.5	2.218	138.4	9.0	20.6
6	2.722			2.241	139.8	8.0	19.8
7	2.697			2.262	141.1	7.2	19.1
8	2.675			2.280	142.3	6.4	18.4
9	2.657			2.296	143.2	5.8	17.8
10	2.640	20.0	54.7	2.310	144.2	5.2	17.3
11	2.625			2.324	145.0	4.7	16.8
12	2.610	19.7	54.5	2.337	145.8	4.1	16.4

SAMPLE SBcN57.9

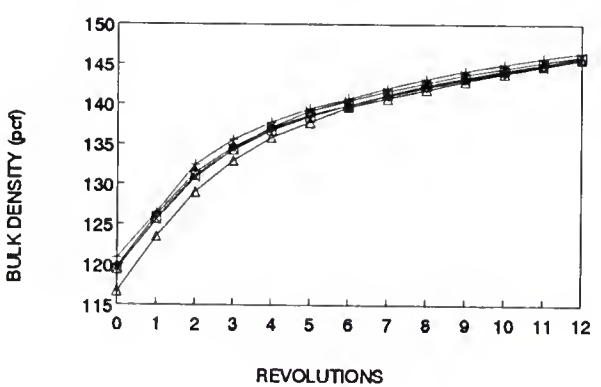
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.245	9.5	21.1	1.869	116.6	23.3	33.1
1	3.065			1.978	123.5	18.6	29.2
2	2.934			2.067	129.0	15.2	26.0
3	2.848			2.129	132.9	12.8	23.8
4	2.787			2.176	135.8	10.7	22.1
5	2.746	18.5	46.6	2.207	137.7	9.5	21.0
6	2.711			2.237	139.6	8.2	20.0
7	2.690			2.254	140.7	7.5	19.3
8	2.669			2.272	141.8	6.8	18.7
9	2.649			2.289	142.8	6.1	18.1
10	2.631	18.0	49.4	2.305	143.8	5.4	17.5
11	2.614			2.320	144.8	4.8	17.0
12	2.598	18.5	51.4	2.334	145.6	4.2	16.5

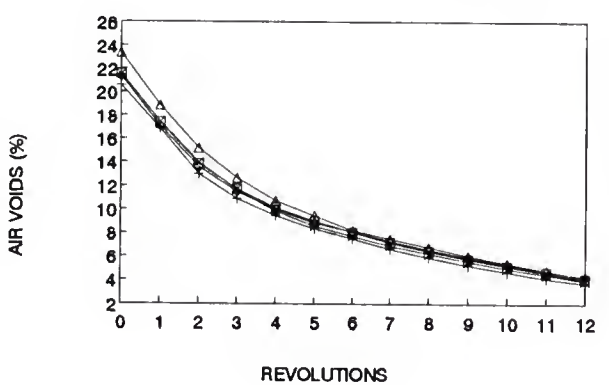
SAMPLE SBcN57.7

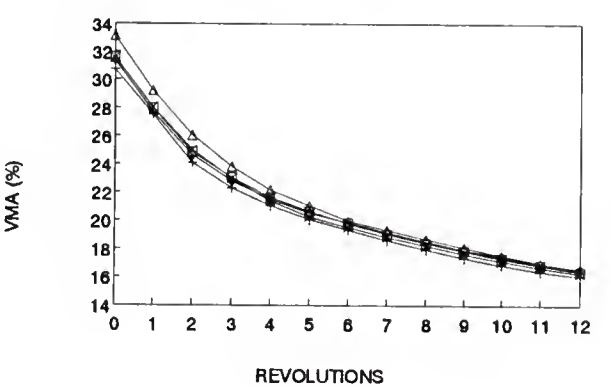
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.119	9.5	22.0	1.936	120.8	20.6	30.7
1	2.960			2.026	126.4	16.6	27.5
2	2.847			2.121	132.4	13.0	24.1
3	2.780			2.172	135.5	10.9	22.3
4	2.736			2.207	137.7	9.4	21.0
5	2.703	19.0	50.7	2.234	139.4	8.3	20.0
6	2.679			2.254	140.7	7.5	19.3
7	2.654			2.275	142.0	6.6	18.6
8	2.633			2.293	143.1	5.9	17.9
9	2.614			2.310	144.2	5.2	17.3
10	2.599	18.5	51.4	2.323	145.0	4.7	16.9
11	2.585			2.336	145.8	4.1	16.4
12	2.574	18.3	51.3	2.346	146.4	3.7	16.0

SAMPLE SBcN57.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.177	9.5	21.6	1.914	119.4	21.5	31.5
1	3.022			2.012	125.5	17.5	28.0
2	2.900			2.096	130.8	14.0	25.0
3	2.824			2.153	134.3	11.7	23.0
4	2.767			2.197	137.1	9.8	21.4
5	2.728	20.5	54.2	2.228	139.1	8.6	20.2
6	2.703			2.249	140.3	7.7	19.5
7	2.680			2.266	141.5	6.9	18.8
8	2.660			2.285	142.6	6.2	18.2
9	2.641			2.302	143.6	5.5	17.6
10	2.625	19.5	53.6	2.316	144.5	5.0	17.1
11	2.611			2.326	145.3	4.5	16.7
12	2.598	19.0	52.6	2.340	146.0	4.0	16.3







MIX ID: BUFORD, COARSE (GA1) GTM DENSIFICATION

RICE:	2.437	BSGcomp	2.537
BSG(Agg)	2.838	HTcomp	2.599
BINDER %	5.7	REVcomp	12

SAMPLE SBcN57.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.603	9.2	25.5	2.333	145.6	4.3	16.5
5	2.560	19.2	53.7	2.340	146.0	4.0	16.2
10	2.568	19.8	55.6	2.344	146.3	3.8	16.1
15	2.560	19.7	55.5	2.346	146.4	3.7	16.0
25	2.543	20.2	57.3	2.351	146.7	3.5	15.9
35	2.532	20.6	58.7	2.354	146.9	3.4	15.7
50	2.519	20.5	58.7	2.358	147.2	3.2	15.6
75	2.498	21.2	61.2	2.364	147.5	3.0	15.4
100	2.485	21.9	63.6	2.368	147.8	2.8	15.2
125	2.475	22.0	64.1	2.371	148.0	2.7	15.1
150	2.466	22.0	64.4	2.374	148.1	2.6	15.0
175	2.458	22.0	64.6	2.376	148.3	2.5	15.0
200	2.452	22.0	64.7	2.378	148.4	2.4	14.9
225	2.447	22.0	64.9	2.380	148.5	2.4	14.8
250	2.442	22.0	65.0	2.381	148.6	2.3	14.8
300	2.432	21.6	64.1	2.384	148.8	2.2	14.7

SAMPLE SBcN57.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.568	10.4	29.2	2.355	147.0	2.9	15.4
5	2.546	21.0	59.5	2.369	147.8	2.8	15.2
10	2.536	21.0	59.8	2.370	147.9	2.7	15.2
15	2.529	21.0	59.9	2.371	148.0	2.7	15.1
25	2.517	21.0	60.2	2.373	148.1	2.6	15.1
35	2.506	21.0	60.5	2.375	148.2	2.6	15.0
50	2.494	21.0	60.8	2.376	148.3	2.5	15.0
75	2.478	21.0	61.2	2.379	148.4	2.4	14.9
100	2.466	21.0	61.5	2.381	148.5	2.3	14.8
125	2.456	21.0	61.7	2.382	148.6	2.3	14.8
150	2.446	21.2	62.5	2.384	148.7	2.2	14.7
175	2.438	21.4	63.3	2.385	148.8	2.1	14.7
200	2.431	21.4	63.5	2.386	148.9	2.1	14.6
225	2.425	21.6	64.3	2.387	148.9	2.1	14.6
250	2.419	21.6	64.4	2.388	149.0	2.0	14.6
300	2.410	21.1	63.2	2.389	149.1	2.0	14.5

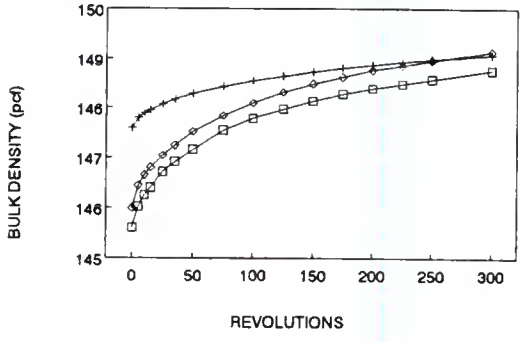
SAMPLE SBcN57.15

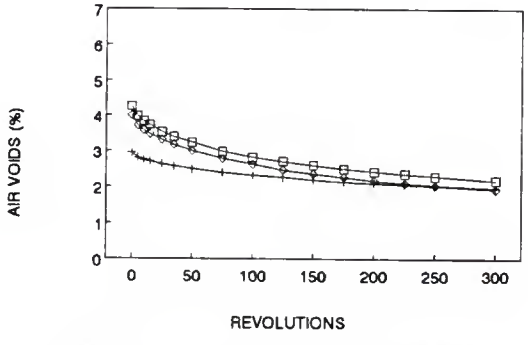
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.596	9.5	26.4	2.340	146.0	4.0	16.5
5	2.570	19.8	55.6	2.347	146.4	3.7	16.0
10	2.558	20.0	56.4	2.350	146.6	3.6	15.9
15	2.549	20.5	58.0	2.353	146.8	3.5	15.8
25	2.535	20.5	57.8	2.356	147.0	3.3	15.7
35	2.523	20.5	58.1	2.360	147.2	3.2	15.6
50	2.507	20.7	59.6	2.364	147.5	3.0	15.4
75	2.486	21.0	60.9	2.369	147.8	2.8	15.2
100	2.473	20.9	61.0	2.373	148.1	2.6	15.1
125	2.460	21.0	61.6	2.377	148.3	2.5	14.9
150	2.450	20.9	61.6	2.380	148.5	2.4	14.8
175	2.442	20.9	61.8	2.382	148.6	2.3	14.8
200	2.434	20.9	62.0	2.384	148.8	2.2	14.7
225	2.428	20.9	62.1	2.386	148.9	2.1	14.6
250	2.422	20.9	62.3	2.387	149.0	2.0	14.6
300	2.412	21.0	62.6	2.390	149.1	1.9	14.5

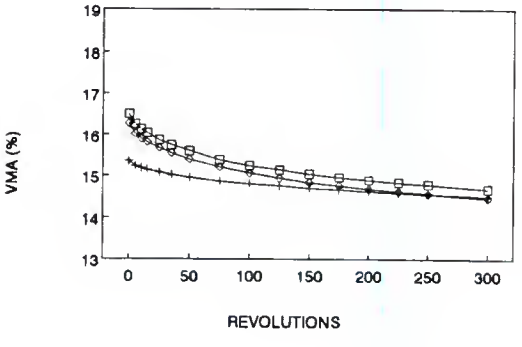
AVERAGE

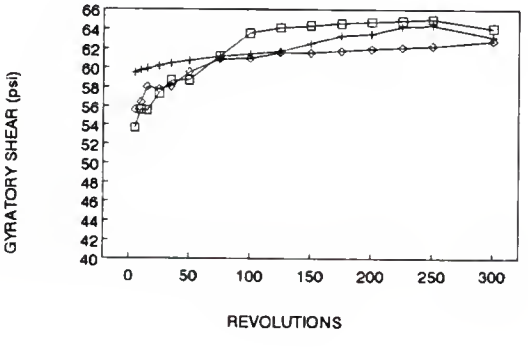
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	27.4	2.349	146.6	5.6	96.4	15.9
5	56.6	2.364	146.9	5.4	96.6	15.7
10	57.7	2.357	147.1	3.5	96.7	15.7
15	57.7	2.369	147.2	3.2	96.8	15.6
25	58.6	2.362	147.4	3.1	96.9	15.5
35	59.6	2.364	147.5	3.0	97.0	15.4
50	59.7	2.367	147.7	2.9	97.1	15.3
75	61.2	2.372	148.0	2.7	97.3	15.1
100	62.5	2.374	148.2	2.6	97.4	15.0
125	62.9	2.377	148.3	2.5	97.5	14.9
150	63.5	2.379	148.4	2.4	97.6	14.9
175	64.0	2.381	148.5	2.3	97.7	14.8
200	64.1	2.382	148.6	2.3	97.7	14.8
225	64.6	2.383	148.7	2.2	97.8	14.7
250	64.7	2.384	148.8	2.2	97.8	14.7
300	63.6	2.387	148.9	2.1	97.9	14.6

MIX ID: BUFORD, COARSE (COMPACTED TO FIELD DENSITY)









MIX ID: BUFORD, FINE (GA2)

GTM COMPACTION

RICE: 2.451
BSG(Agg) 2.635
BINDER % 5.5

SAMPLE SBfN55.1

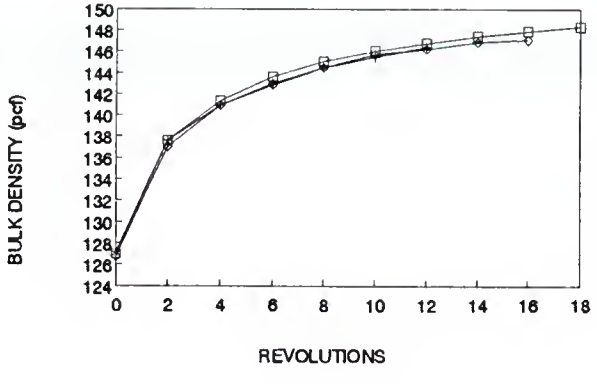
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.835	9.0	22.9	2.035	127.0	17.0	27.0
2	2.616	16.5	51.0	2.205	137.6	10.0	20.9
4	2.547	17.5	49.6	2.265	141.3	7.6	18.6
6	2.507	16.5	53.2	2.301	143.6	6.1	17.5
8	2.462	19.0	55.2	2.324	145.0	5.2	16.6
10	2.465	16.6	54.4	2.340	146.0	4.5	16.1
12	2.453	16.5	54.4	2.352	146.8	4.0	15.7
14	2.442	16.2	53.6	2.362	147.4	3.6	15.3
16	2.434	16.0	53.4	2.370	147.9	3.3	15.0
18	2.427	17.5	52.0	2.377	148.3	3.0	14.6

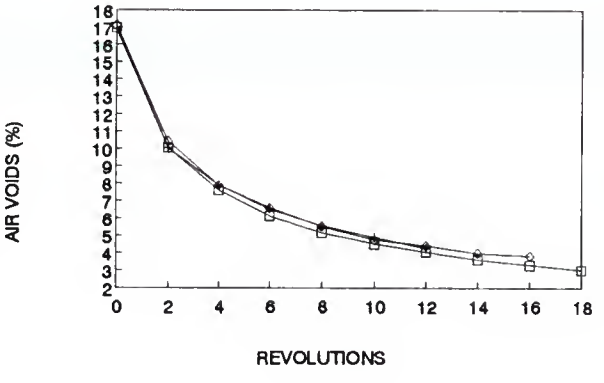
SAMPLE SBfN55.4

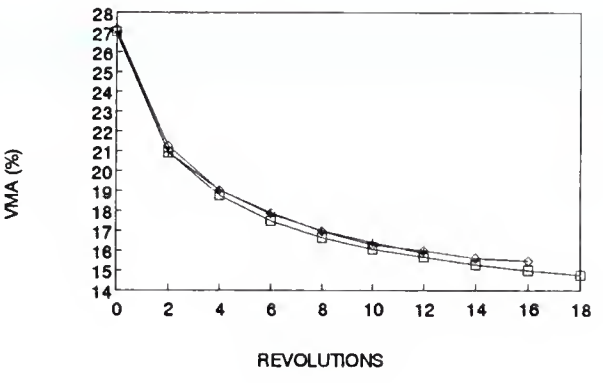
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.636	9	22.9	2.037	127.1	16.9	26.9
2	2.620	18	49.6	2.205	137.6	10.0	20.9
4	2.559	16.2	51.3	2.256	140.9	7.9	19.0
6	2.522	18	51.5	2.291	143.0	6.5	17.6
8	2.496	17.5	50.6	2.315	144.5	5.5	17.0
10	2.479	17	49.5	2.331	145.4	4.9	16.4
12	2.463	17	49.6	2.346	146.4	4.3	15.9
14							
16							
18							

SAMPLE SBfN55.5

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.630	9	22.9	2.031	126.8	17.1	27.1
2	2.616	16.5	45.5	2.196	137.0	10.4	21.2
4	2.546	17	48.2	2.258	140.9	7.9	19.0
6	2.511	17	48.9	2.289	142.9	6.6	17.9
8	2.483	17	49.4	2.315	144.5	5.5	17.0
10	2.462	16.7	48.9	2.335	145.7	4.7	16.3
12	2.454	16.7	49.1	2.343	146.2	4.4	16.0
14	2.443	16.5	48.7	2.353	146.8	4.0	15.6
16	2.439	16	47.3	2.357	147.1	3.8	15.5
16							







MIX ID: BUFORD, FINE (GA2)

GTM COMPACTION

RICE: 2.451
BSG(Agg) 2.635
BINDER % 5.5

SAMPLE SBfN55.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.666	9.0	22.7	2.048	127.8	16.5	26.6
1							
2							
3							
4							
5	2.574	17.0	47.7	2.280	142.3	7.0	18.2

SAMPLE SBfN55.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.679	9.0	22.6	2.019	126.0	17.6	27.6
1	2.738			2.123	132.5	13.4	23.9
2	2.645			2.198	137.1	10.3	21.2
3	2.594			2.241	139.6	8.6	19.6
4	2.565			2.266	141.4	7.5	18.7
5	2.544	20.7	58.7	2.285	142.6	6.6	18.1

SAMPLE SBfN55.8

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.647	9.0	22.8	2.047	127.7	16.5	26.6
1	2.720			2.142	133.7	12.6	23.2
2	2.635			2.211	138.0	9.8	20.7
3	2.589			2.251	140.4	6.2	19.3
4	2.559			2.277	142.1	7.1	18.3
5	2.538	20.5	58.3	2.296	143.3	6.3	17.7

SAMPLE SBfN55.9

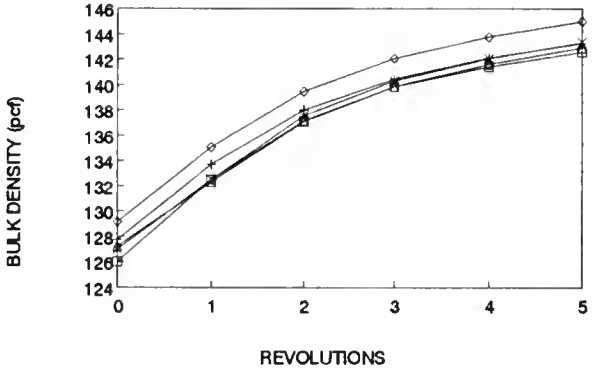
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.813	9.0	23.1	2.070	129.1	15.6	25.8
1	2.690			2.164	135.0	11.7	22.4
2	2.605			2.235	139.5	8.8	19.9
3	2.557			2.277	142.1	7.1	18.3
4	2.527			2.304	143.8	6.0	17.4
5	2.505	17.0	49.0	2.324	145.0	5.2	16.7

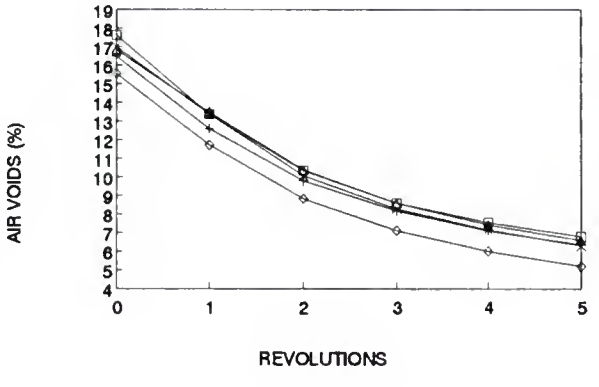
SAMPLE SBfN55.10

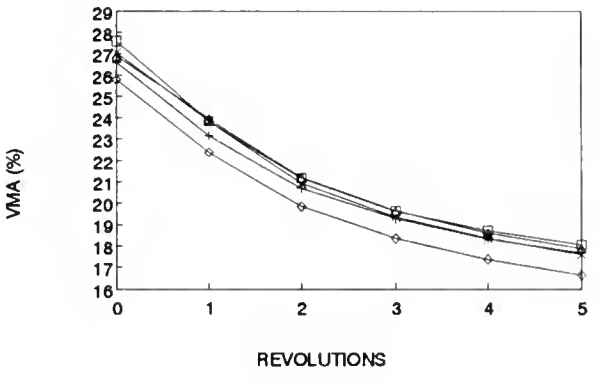
REV	HT	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.882	9.0	22.7	2.039	127.2	16.6	26.9
1	2.752			2.120	132.3	13.5	24.0
2	2.656			2.197	137.1	10.4	21.2
3	2.604			2.241	139.6	8.6	19.6
4	2.571			2.270	141.6	7.4	18.6
5	2.548	19.7	55.6	2.290	142.9	6.6	17.9

SAMPLE SBfN55.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.673	9.0	22.6	2.035	127.0	17.0	27.0
1	2.753			2.123	132.5	13.4	23.6
2	2.652			2.204	137.5	10.1	20.9
3	2.600			2.248	140.3	8.3	19.4
4	2.568			2.276	142.0	7.1	18.4
5	2.545	19.0	53.9	2.297	143.3	6.3	17.6







MIX ID: BUFORD, FINE (GA2) GTM DENSIFICATION

RICE:	2.451	BSGcomp	2.295
BSG(Agg)	2.636	HTcomp	2.542
BINDER %	5.5	REVcomp	5

SAMPLE SBIN55.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.540	9.5	27.6	2.297	143.3	6.3	17.6
5	2.504	19.6	57.1	2.315	144.5	5.5	17.0
10	2.489	20.0	56.0	2.323	144.9	5.2	16.7
15	2.476	19.1	55.7	2.329	145.4	5.0	16.5
25	2.451	19.0	55.9	2.342	146.2	4.4	16.0
35	2.439	19.0	56.2	2.348	146.5	4.2	15.8
50	2.420	19.0	56.7	2.356	147.1	3.8	15.4
75	2.400	18.8	56.5	2.366	147.8	3.4	15.1
100	2.387	18.3	55.5	2.375	148.2	3.1	14.8
125	2.378	18.1	54.9	2.380	148.5	2.9	14.7
150	2.371	18.0	54.6	2.383	148.7	2.8	14.5
175	2.364	17.7	54.0	2.387	148.9	2.6	14.4
200	2.357	17.0	52.0	2.390	149.2	2.5	14.3
225	2.352	16.7	51.2	2.393	149.3	2.4	14.2
250	2.346	16.3	50.1	2.396	149.5	2.2	14.1
300	2.334	16.1	49.8	2.402	149.9	2.0	13.9

SAMPLE SBIN55.13

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.561	9.8	27.0	2.278	142.1	7.1	18.3
5	2.520	19.5	56.6	2.302	143.6	6.1	17.4
10	2.505	19.0	54.6	2.312	144.3	5.7	17.1
15	2.491	19.0	55.0	2.319	144.7	5.4	16.8
25	2.470	18.6	54.9	2.331	145.5	4.9	16.4
35	2.454	18.1	53.2	2.340	146.0	4.5	16.1
50	2.435	18.0	53.5	2.352	146.7	4.1	15.7
75	2.415	18.0	53.8	2.363	147.5	3.6	15.2
100	2.400	17.9	53.8	2.372	148.0	3.2	14.9
125	2.389	17.2	52.0	2.378	148.4	3.0	14.7
150	2.380	17.0	51.5	2.384	148.7	2.7	14.5
175	2.372	16.5	50.2	2.388	149.0	2.6	14.3
200	2.366	16.5	50.3	2.392	149.3	2.4	14.2
225	2.359	16.5	50.5	2.396	149.5	2.2	14.1
250	2.352	16.5	50.6	2.400	149.8	2.1	13.9
300	2.340	16.7	51.5	2.407	150.2	1.8	13.7

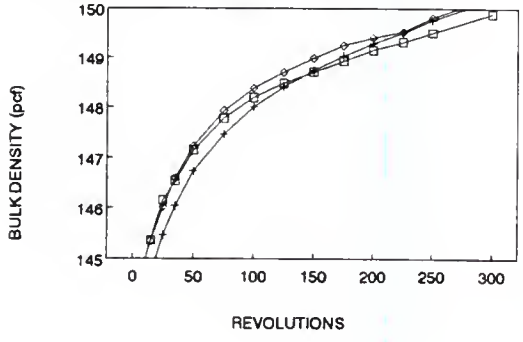
SAMPLE SBIN55.14

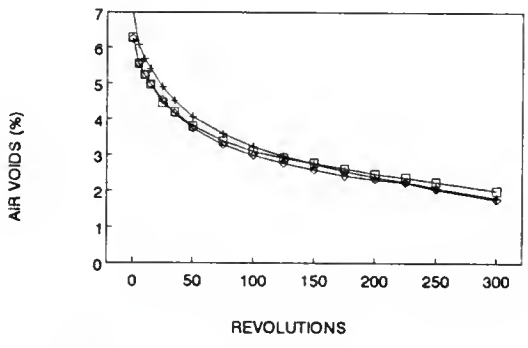
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.539	11.0	31.3	2.296	143.4	6.3	17.6
5	2.506	19.0	54.7	2.315	144.5	5.5	17.0
10	2.490	19.0	55.1	2.323	144.9	5.2	16.7
15	2.477	18.9	55.1	2.329	145.4	5.0	16.5
25	2.455	18.9	55.5	2.340	146.0	4.5	16.1
35	2.436	18.9	55.9	2.349	146.6	4.2	15.7
50	2.418	18.1	54.0	2.359	147.2	3.7	15.4
75	2.398	17.8	53.6	2.371	147.9	3.3	15.0
100	2.382	17.1	51.8	2.378	148.4	3.0	14.7
125	2.372	17.0	51.7	2.383	148.7	2.8	14.5
150	2.363	17.0	51.9	2.388	149.0	2.6	14.4
175	2.355	17.0	52.1	2.392	149.2	2.4	14.2
200	2.35	16.8	51.6	2.394	149.4	2.3	14.1
225	2.346	16.5	50.8	2.396	149.5	2.2	14.1
250	2.337	16.2	50.0	2.401	149.8	2.0	13.9
300	2.323	16.0	49.7	2.408	150.3	1.8	13.6

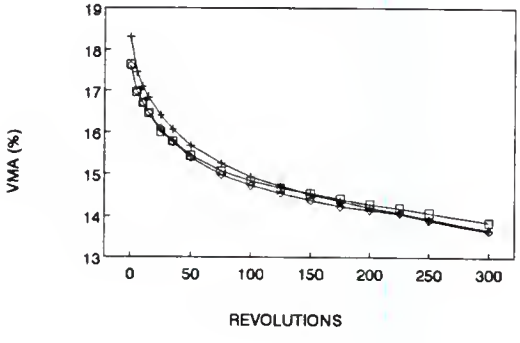
AVERAGE

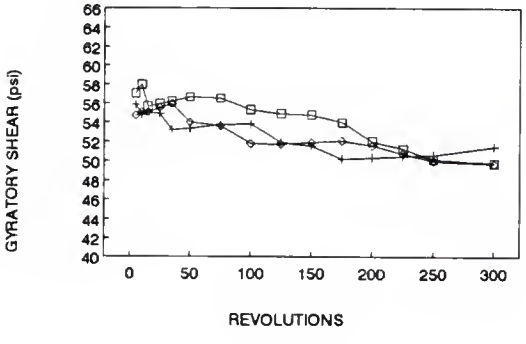
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	27.5	2.287	142.7	6.7	93.3	18.0
5	56.4	2.309	144.1	5.8	94.2	17.2
10	56.4	2.317	144.6	5.5	94.5	16.9
15	56.4	2.324	145.0	5.2	94.8	16.6
25	55.4	2.337	145.8	4.7	95.3	16.2
35	54.7	2.344	146.3	4.3	95.7	15.9
50	55.0	2.355	146.9	3.9	96.1	15.5
75	55.2	2.366	147.6	3.5	96.5	15.2
100	54.6	2.373	148.1	3.2	96.8	14.9
125	53.4	2.379	148.4	2.9	97.1	14.7
150	53.2	2.383	148.7	2.8	97.2	14.5
175	52.1	2.387	149.0	2.6	97.4	14.4
200	51.2	2.391	149.2	2.4	97.6	14.2
225	50.9	2.394	149.4	2.3	97.7	14.1
250	50.4	2.398	149.6	2.2	97.8	14.0
300	50.6	2.405	150.0	1.9	98.1	13.8

MIX ID: BUFORD, FINE (COMPACTED TO FIELD DENSITY)









MIX ID: BUFGRD, FINE (GA2) GTM DENSIFICATION RETEST SAMPLES

RICE:	2.451	BSGcomp	2.295
BSG(Agg)	2.635	HTcomp	2.542
BINDER %	5.5	REVcomp	5

SAMPLE SBfN55.17

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.537	10.0	28.4	2.300	143.5	6.2	17.5
5	2.502	20.0	57.7	2.317	144.6	5.5	16.9
10	2.491	20.5	59.4	2.323	144.9	5.2	16.7
15	2.484	20.5	59.6	2.326	145.1	5.1	16.6
25	2.473	20.5	59.8	2.332	145.5	4.9	16.4
35	2.465	20.0	56.5	2.336	145.7	4.7	16.2
50	2.456	20.0	56.8	2.340	146.0	4.5	16.1
75	2.444	20.0	59.1	2.346	146.4	4.3	15.9
100	2.433	20.5	60.8	2.352	146.7	4.1	15.7
125	2.425	20.5	61.0	2.356	147.0	3.9	15.5
150	2.422	20.5	61.1	2.357	147.1	3.8	15.5
175	2.417	21.0	62.7	2.360	147.2	3.7	15.4
200	2.413	21.0	62.8	2.362	147.4	3.7	15.3
225	2.410	21.0	62.9	2.363	147.5	3.6	15.3
250	2.406	21.0	63.0	2.365	147.6	3.5	15.2
300	2.400	21.5	64.6	2.368	147.8	3.4	15.1

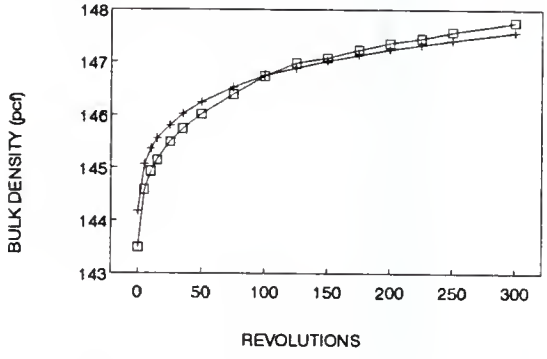
SAMPLE SBfN55.16

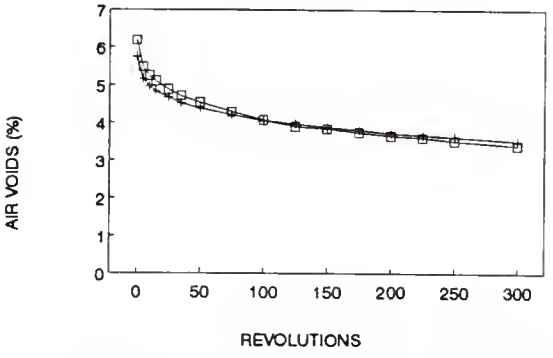
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.525	10.0	28.6	2.310	144.2	5.7	17.1
5	2.493	19.3	56.4	2.325	145.1	5.2	16.6
10	2.482	20.0	56.1	2.330	145.4	5.0	16.5
15	2.475	20.5	59.6	2.333	145.6	4.8	16.3
25	2.466	20.5	60.0	2.337	145.8	4.7	16.2
35	2.456	21.0	61.7	2.340	146.0	4.5	16.1
50	2.450	21.0	61.9	2.344	146.2	4.4	15.9
75	2.440	21.0	62.1	2.348	146.5	4.2	15.8
100	2.432	21.0	62.3	2.352	146.7	4.1	15.7
125	2.427	21.5	63.9	2.354	146.9	4.0	15.6
150	2.422	21.5	64.1	2.356	147.0	3.9	15.5
175	2.418	21.5	64.2	2.358	147.1	3.8	15.4
200	2.414	21.5	64.3	2.360	147.2	3.7	15.4
225	2.411	21.5	64.3	2.361	147.3	3.7	15.3
250	2.408	21.5	64.4	2.362	147.4	3.6	15.3
300	2.402	21.5	64.6	2.365	147.6	3.5	15.2

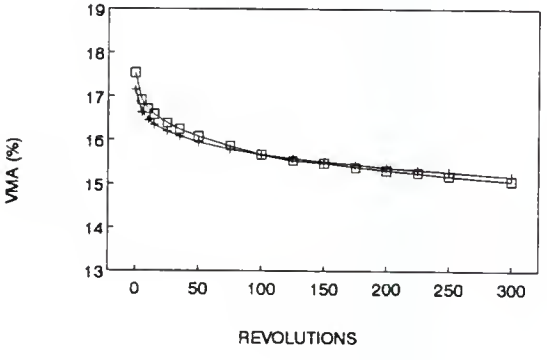
AVERAGE

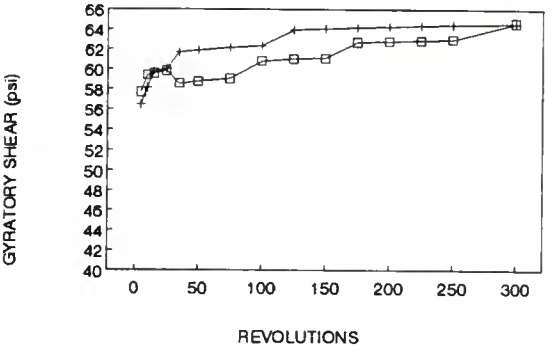
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	28.5	2.305	143.8	6.0	94.0	17.3
5	57.1	2.321	144.8	5.3	94.7	16.8
10	58.8	2.326	145.1	5.1	94.9	16.6
15	59.7	2.329	145.3	5.0	95.0	16.5
25	59.9	2.334	145.6	4.8	95.2	16.3
35	60.1	2.336	145.9	4.6	95.4	16.2
50	60.3	2.342	146.1	4.5	95.5	16.0
75	60.6	2.347	146.5	4.2	95.8	15.8
100	61.6	2.352	146.7	4.1	95.9	15.7
125	62.5	2.355	146.9	3.9	96.1	15.6
150	62.6	2.357	147.0	3.9	96.1	15.5
175	63.4	2.359	147.2	3.8	96.2	15.4
200	63.5	2.361	147.3	3.7	96.3	15.3
225	63.6	2.362	147.4	3.6	96.4	15.3
250	63.7	2.364	147.5	3.6	96.4	15.2
300	64.6	2.367	147.7	3.4	96.6	15.1

MIX ID: BUFGRD, FINE (COMPACTED TO FIELD DENSITY)









MIX ID: RUBY (GA3)

GTM COMPACTION

RICE: 2.491
BSG(Agg) 2.732
BINDER % 5.6

SAMPLE SRfN56.3

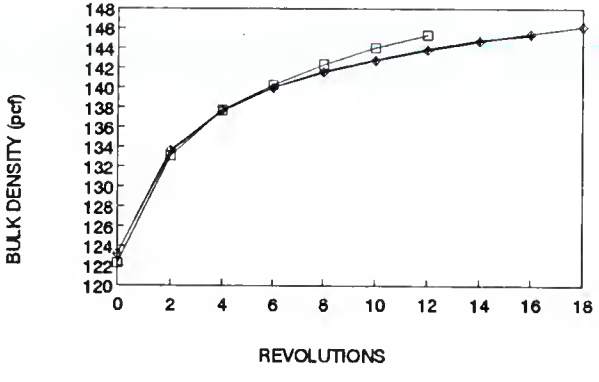
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.213	9.5	21.3	1.959	122.2	21.4	32.3
2	2.951	20.0	48.9	2.132	133.1	14.4	26.3
4	2.852	20.0	50.6	2.207	137.7	11.4	23.8
6	2.800	20.0	51.5	2.247	140.2	9.8	22.3
8	2.759	20.3	53.1	2.261	142.3	8.4	21.2
10	2.726	20.3	53.7	2.308	144.1	7.3	20.2
12	2.702	20.0	53.4	2.329	145.3	6.5	19.5

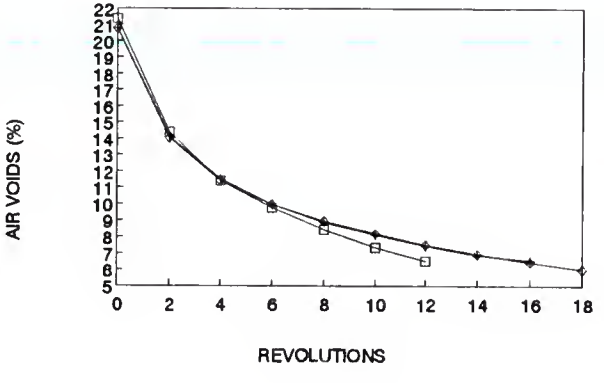
SAMPLE SRfN56.4

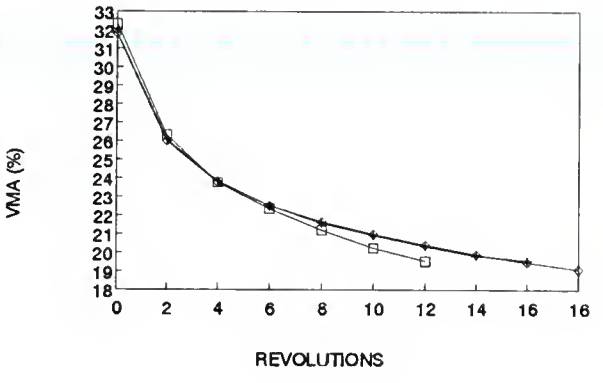
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.176	9.5	21.6	1.973	123.1	20.8	31.8
2	2.929	18.6	46.3	2.140	133.5	14.1	26.1
4	2.843	20.5	52.0	2.204	137.6	11.5	23.6
6	2.794	21.3	55.0	2.243	140.0	10.0	22.5
8	2.761	22	57.5	2.270	141.6	8.9	21.6
10	2.736	22	58.0	2.289	142.8	8.1	20.9
12	2.716	22	58.4	2.306	143.9	7.4	20.3
14	2.701	21.7	58.0	2.320	144.8	6.9	19.8
16	2.692	21.5	57.8	2.326	145.3	6.5	19.6

SAMPLE SRfN56.5

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.161	9.5	21.7	1.974	123.2	20.8	31.8
2	2.913	20.7	51.3	2.142	133.8	14.0	26.0
4	2.827	21.7	55.4	2.207	137.7	11.4	23.7
6	2.782	22.7	58.9	2.243	139.9	10.0	22.5
8	2.751	22.3	58.5	2.268	141.5	9.0	21.6
10	2.726	22	58.2	2.287	142.7	8.2	21.0
12	2.708	21.5	57.3	2.304	143.8	7.5	20.4
14	2.691	21.5	57.7	2.319	144.7	6.9	19.9
16	2.677	21.3	57.4	2.331	145.4	6.4	19.5
18	2.664	21	56.9	2.342	146.1	6.0	19.1







MIX ID: RUBY (GA3)

GTM COMPACTION

RICE: 2.491
BSG(Agg) 2.732
BINDER % 5.6

SAMPLE SRfN56.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.178	9.5	21.0	1.973	123.1	20.8	31.6
2	2.929	19.6	46.3	2.140	133.5	14.1	29.1
4	2.843	20.5	52.0	2.204	137.6	11.5	23.8
6	2.794	21.3	55.0	2.243	140.0	10.0	22.5
8	2.761	22.0	57.5	2.270	141.6	9.0	21.6
10	2.738	22.0	58.0	2.289	142.8	8.1	20.9
12	2.719	22.0	56.4	2.306	143.9	7.4	20.3
14	2.701	21.7	59.0	2.320	144.8	6.9	19.8
16	2.692	21.5	57.6	2.328	145.3	6.5	19.6

SAMPLE SRfN56.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.152	9.0	20.6	1.999	124.8	19.7	30.9
1	3.032			2.079	129.7	16.6	28.2
2	2.932			2.150	134.1	13.7	25.7
3	2.860			2.186	136.6	12.2	24.4
4	2.846			2.214	138.2	11.1	23.5
5	2.818	20.0	51.2	2.230	139.2	10.2	22.7
6	2.801			2.250	140.4	9.7	22.3
7	2.783			2.265	141.3	9.1	21.8
8	2.767			2.279	142.1	8.6	21.3
9	2.752			2.290	142.9	8.1	20.9
10	2.739	20.4	53.7	2.301	143.6	7.6	20.5
11	2.726			2.312	144.3	7.2	20.1
12	2.716			2.320	144.8	6.9	19.8
13	2.706			2.329	145.3	6.5	19.5
14	2.699			2.336	145.8	6.2	19.3
15	2.690			2.343	146.2	5.9	19.0
16	2.683	20.4	54.9	2.349	146.6	5.7	18.8

SAMPLE SRfN56.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.152	9.0	20.6	1.999	124.7	19.6	31.0
1	3.032			2.077	129.6	16.6	28.2
2	2.932			2.148	134.0	13.9	25.8
3	2.860			2.186	136.4	12.2	24.5
4	2.846			2.213	138.1	11.2	23.5
5	2.818	21.0	53.6	2.235	139.4	10.3	22.8
6	2.801			2.249	140.3	9.6	22.3
7	2.783			2.263	141.2	9.2	21.8
8	2.767			2.276	142.0	8.6	21.4
9	2.752			2.286	142.6	8.1	20.9
10	2.739	19.7	51.9	2.299	143.5	7.7	20.6
11	2.726			2.310	144.1	7.3	20.2
12	2.716			2.319	144.7	6.9	19.9
13	2.706			2.327	145.2	6.6	19.6
14	2.699			2.334	145.6	6.3	19.4
15	2.69			2.341	146.1	6.0	19.1
16	2.683	20.0	53.6	2.347	146.5	5.8	18.9

SAMPLE SRfN56.8

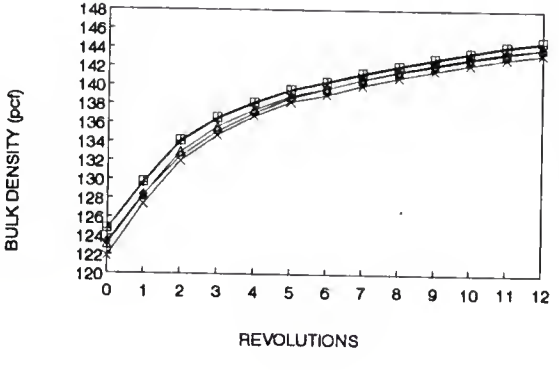
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.190	9.0	20.4	1.976	123.3	20.7	31.7
1	3.065			2.057	128.4	17.4	29.0
2	2.971			2.122	132.4	14.8	26.7
3	2.912			2.165	135.1	13.1	25.2
4	2.870			2.197	137.1	11.8	24.1
5	2.838	21.0	53.4	2.221	138.6	10.8	23.2
6	2.817			2.238	139.7	10.2	22.7
7	2.797			2.254	140.7	9.5	22.1
8	2.780			2.266	141.5	9.0	21.6
9	2.765			2.280	142.3	8.5	21.2
10	2.752	21.7	56.9	2.291	143.0	8.0	20.8
11	2.740			2.301	143.6	7.6	20.5
12	2.731			2.308	144.1	7.3	20.2
13	2.722			2.316	144.5	7.0	20.0
14	2.714			2.323	145.0	6.7	19.7
15	2.706			2.328	145.3	6.5	19.6
16	2.700	21.7	59.0	2.335	145.7	6.3	19.3

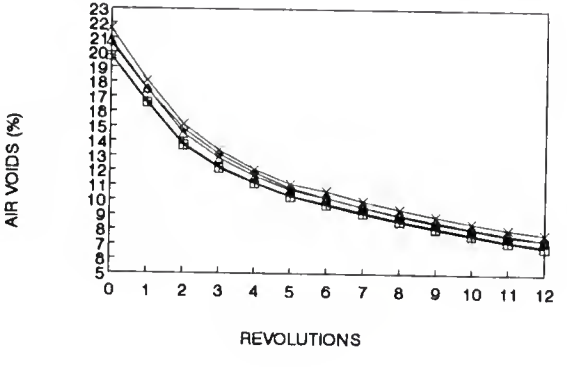
SAMPLE SRfN56.9

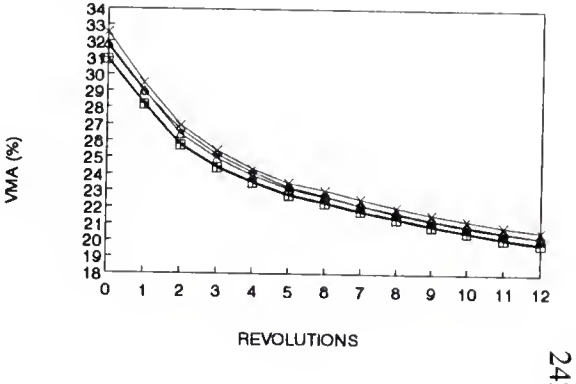
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.182	9.0	20.4	1.972	123.1	20.9	31.6
1	3.054			2.055	128.2	17.5	29.0
2	2.947			2.130	132.9	14.5	26.4
3	2.869			2.172	135.6	12.9	24.9
4	2.850			2.202	137.4	11.8	23.9
5	2.821	20.5	52.4	2.225	138.8	10.7	23.1
6	2.804			2.238	139.7	10.1	22.7
7	2.785			2.254	140.6	9.5	22.1
8	2.769			2.267	141.4	9.0	21.7
9	2.755			2.279	142.2	8.5	21.3
10	2.742	19.7	51.6	2.289	142.8	8.1	20.9
11	2.730			2.299	143.5	7.7	20.6
12	2.719			2.308	144.0	7.3	20.2
13	2.709			2.317	144.6	7.0	19.9
14	2.699			2.325	145.1	6.6	19.6
15	2.690			2.333	145.6	6.3	19.4
16	2.681	19.5	52.5	2.341	146.1	6.0	19.1

SAMPLE SRfN56.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.220	9.5	21.3	1.952	121.8	21.6	32.5
1	3.080			2.041	127.4	18.1	29.5
2	2.973			2.114	131.9	15.1	26.9
3	2.912			2.159	134.7	13.3	25.4
4	2.869			2.191	136.7	12.0	24.3
5	2.838	20.7	52.0	2.215	138.2	11.1	23.5
6	2.822			2.227	139.0	10.6	23.0
7	2.802			2.243	140.0	9.9	22.5
8	2.785			2.257	140.8	9.4	22.0
9	2.770			2.269	141.6	8.9	21.6
10	2.757	20.5	53.7	2.280	142.3	8.5	21.2
11	2.745			2.290	142.9	8.1	20.9
12	2.735			2.299	143.4	7.7	20.6
13	2.725			2.307	143.9	7.4	20.3
14	2.716			2.314	144.4	7.1	20.0
15	2.707			2.322	144.9	6.8	19.8
16	2.699	20.0	53.5	2.329	145.3	6.5	19.5







MIX ID: RUBY (GA3)

GTM DENSIFICATION

RICE:	2.491	BSGcomp	2.338
BSG(Agg)	2.732	HTcomp	2.690
BINDER %	5.6	REVcomp	16

SAMPLE SRIN56.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.675	10.5	28.5	2.351	146.7	5.6	18.6
5	2.645	20.0	54.6	2.368	147.8	4.9	18.2
10	2.640	21.0	57.4	2.371	147.9	4.6	18.1
15	2.633	21.0	57.6	2.375	148.2	4.7	17.9
25	2.623	20.5	56.4	2.380	148.5	4.4	17.6
35	2.616	20.0	55.2	2.384	148.8	4.3	17.6
50	2.606	20.0	55.4	2.390	149.2	4.0	17.4
75	2.592	19.5	54.5	2.398	149.6	3.7	17.2
100	2.582	19.5	54.5	2.403	150.0	3.5	17.0
125	2.574	19.5	54.7	2.408	150.2	3.3	16.8
150	2.569	19.0	53.4	2.411	150.4	3.2	16.7
175	2.563	19.0	53.5	2.414	150.6	3.1	16.6
200	2.558	19.0	53.6	2.417	150.8	3.0	16.5
225	2.554	19.0	53.7	2.419	150.9	2.9	16.4
250	2.550	19.0	53.6	2.421	151.1	2.8	16.3
300	2.545	19.0	53.9	2.424	151.3	2.7	16.2

SAMPLE SRIN56.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.644	10.5	28.7	2.379	148.4	4.5	17.8
5	2.616	19.5	53.6	2.391	149.2	4.0	17.4
10	2.606	20.0	55.5	2.394	149.4	3.9	17.5
15	2.600	20.0	56.5	2.398	149.6	3.7	17.1
25	2.589	20.5	57.1	2.403	149.9	3.5	17.0
35	2.580	20.5	57.3	2.407	150.2	3.4	16.8
50	2.571	20.5	57.5	2.411	150.4	3.2	16.7
75	2.560	20.5	57.6	2.416	150.7	3.0	16.5
100	2.551	20.5	56.0	2.420	151.0	2.9	16.4
125	2.544	20.5	58.1	2.423	151.2	2.7	16.3
150	2.539	20.5	56.3	2.426	151.3	2.7	16.2
175	2.534	20.5	56.4	2.427	151.4	2.6	16.1
200	2.531	20.5	56.4	2.428	151.5	2.5	16.1
225	2.527	20.0	57.1	2.430	151.6	2.4	16.0
250	2.524	20.0	57.2	2.431	151.7	2.4	16.0
300	2.516	20.0	57.5	2.434	151.9	2.5	15.9

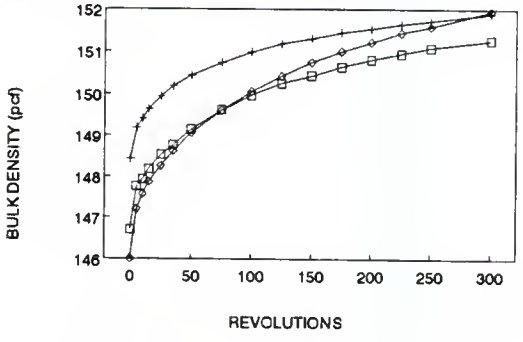
SAMPLE SRIN56.15

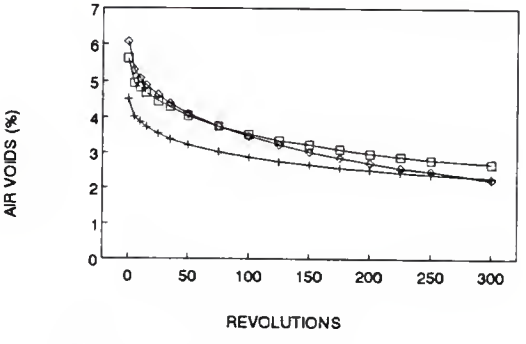
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.668	11.5	30.9	2.340	146.0	6.1	19.2
5	2.655	21.0	57.1	2.359	147.2	5.3	18.5
10	2.645	21.5	56.7	2.365	147.6	5.1	18.3
15	2.637	21.5	56.6	2.370	147.9	4.9	18.1
25	2.626	21.5	59.1	2.376	148.3	4.6	17.9
35	2.616	21.0	57.9	2.382	148.6	4.4	17.7
50	2.604	21.0	58.2	2.389	149.1	4.1	17.5
75	2.589	21.0	56.5	2.398	149.6	3.7	17.2
100	2.577	20.5	57.4	2.403	150.0	3.5	16.9
125	2.567	20.5	57.6	2.410	150.4	3.2	16.7
150	2.558	21.0	59.2	2.416	150.7	3.0	16.5
175	2.551	21.0	59.4	2.420	151.0	2.9	16.4
200	2.545	20.5	58.1	2.423	151.2	2.7	16.3
225	2.539	20.0	56.8	2.427	151.4	2.6	16.1
250	2.535	20.0	56.9	2.429	151.6	2.5	16.1
300	2.525	20.0	57.2	2.435	151.9	2.2	15.9

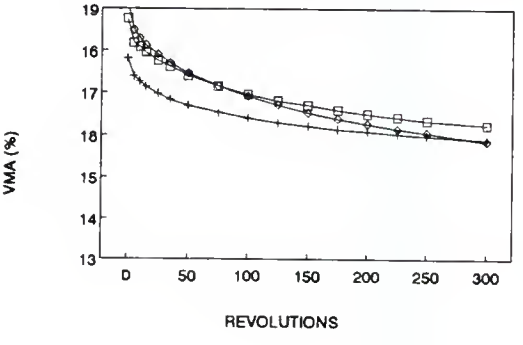
AVERAGE

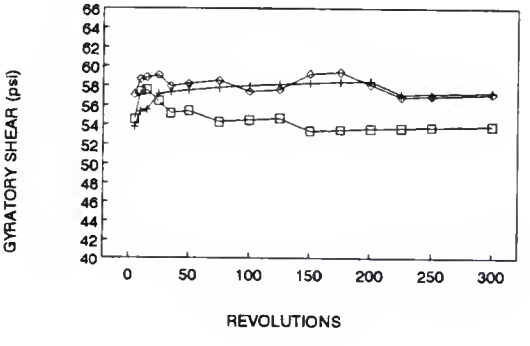
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	28.5	2.365	147.6	5.1	94.9	18.5
5	54.2	2.379	148.5	4.5	95.5	17.6
10	56.4	2.383	148.7	4.4	95.6	17.7
15	56.5	2.388	149.0	4.2	95.8	17.5
25	56.8	2.392	149.2	4.0	96.0	17.4
35	56.3	2.395	149.5	3.8	96.2	17.2
50	56.5	2.401	149.8	3.6	96.4	17.1
75	56.0	2.407	150.2	3.4	96.6	16.8
100	56.2	2.411	150.5	3.2	96.8	16.7
125	56.4	2.415	150.7	3.0	97.0	16.5
150	55.8	2.418	150.9	2.9	97.1	16.5
175	55.9	2.420	151.0	2.8	97.2	16.4
200	56.0	2.423	151.2	2.7	97.3	16.3
225	55.4	2.425	151.3	2.7	97.5	16.2
250	55.5	2.426	151.4	2.6	97.4	16.2
300	55.6	2.429	151.6	2.5	97.5	16.1

MIX ID: RUBY (COMPACTED TO FIELD DENSITY)









MIX ID. MTVIEW (GA4)

GTM COMPACTION

RICE: 2.464
BSG(Agg) 2.667
BINDER % 5.9

SAMPLE SGSt596

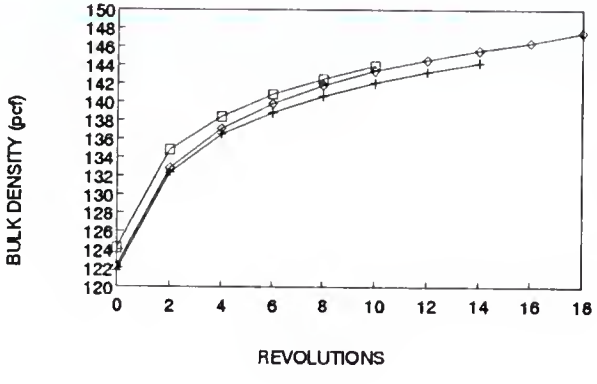
REV	HT.	ARP	Gs	BSG	B DENS	A V.	VMA
0	3.012	9.0	21.6	1.991	124.2	19.2	29.8
2	2.778	19.5	50.7	2.160	134.8	12.3	23.8
4	2.704	19.9	53.1	2.217	138.4	10.0	21.8
6	2.657	20.0	54.3	2.257	140.8	8.4	20.4
8	2.628	20.0	55.0	2.283	142.5	7.3	19.4
10	2.600	19.5	54.1	2.306	143.9	6.4	18.6

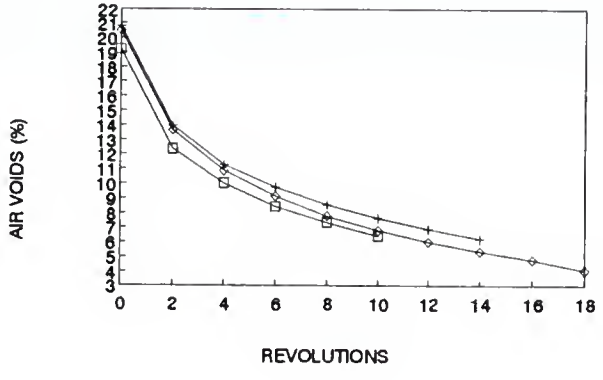
SAMPLE SGSt597

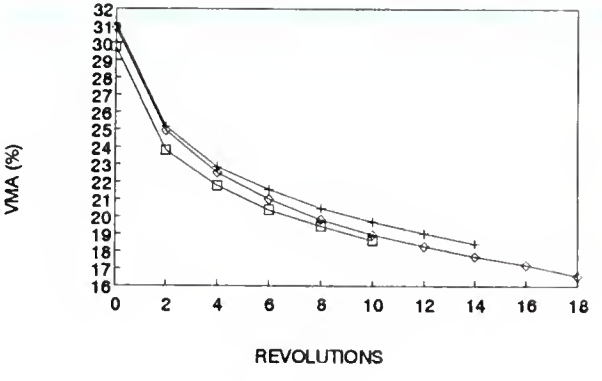
REV	HT.	ARP	Gs	BSG	B DENS	A V.	VMA
0	3.058	9.2	21.7	1.951	121.8	20.8	31.2
2	2.814	8.6	22.6	2.120	132.3	13.9	25.2
4	2.729	20.1	53.1	2.187	136.4	11.3	22.9
6	2.683	20.7	55.7	2.224	138.8	9.7	21.5
8	2.648	21.0	57.2	2.253	140.6	8.5	20.5
10	2.622	20.8	57.2	2.276	142.0	7.6	19.7
12	2.600	21.0	58.3	2.295	143.2	6.9	19.0
14	2.582	20.9	58.4	2.311	144.2	6.2	18.5

SAMPLE SGSt593

REV	HT.	ARP	Gs	BSG	B DENS	A V.	VMA
0	3.019	9.0	21.5	1.959	122.3	20.5	30.9
2	2.780			2.128	132.8	13.7	24.9
4	2.693	20.0	53.8	2.196	137.1	10.9	22.5
6	2.641			2.240	139.7	9.1	21.0
8	2.603			2.272	141.8	7.6	19.8
10	2.575	20.5	57.4	2.297	143.3	6.6	19.0
12	2.554			2.318	144.5	6.0	18.3
14	2.536	20.0	56.9	2.332	145.5	5.3	17.7
16	2.521			2.348	146.4	4.8	17.2
18	2.502	19.3	55.7	2.364	147.5	4.1	16.6







MIX ID: MT VIEW (GA4)

GTM COMPACTION

RICE: 2.464
BSG(Agg) 2.667
BINDER % 5.9

SAMPLE SGSt59.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.058	9.2	21.7	1.951	121.8	20.8	31.2
2	2.814	19.8	50.8	2.120	132.3	13.9	25.2
4	2.729	20.1	53.1	2.187	136.4	11.3	22.9
6	2.683	20.7	55.7	2.224	138.8	9.7	21.5
8	2.648	21.0	57.2	2.253	140.6	8.5	20.5
10	2.622	20.8	57.2	2.276	142.0	7.6	19.7
12	2.600	21.0	58.3	2.295	143.2	6.9	19.0
14	2.582	20.9	58.4	2.311	144.2	6.2	18.5

SAMPLE SGSt59.9

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.109	9.5	22.0	1.930	120.4	21.7	31.9
1	2.950			2.034	126.9	17.4	28.2
2	2.840			2.113	131.9	14.2	25.4
3	2.765			2.155	134.5	12.5	24.0
4	2.730			2.182	136.2	11.4	23.0
5	2.726	19.0	50.3	2.201	137.4	10.7	22.3
6	2.705			2.218	138.4	10.0	21.7
7	2.683			2.235	139.5	9.5	21.1
8	2.668			2.249	140.4	8.7	20.6
9	2.654			2.261	141.1	8.2	20.2
10	2.640	19.5	53.3	2.273	141.8	7.7	19.8
11	2.630			2.282	142.4	7.4	19.5
12	2.618			2.292	143.0	7.0	19.1
13	2.606			2.301	143.6	6.6	18.8
14	2.599			2.309	144.1	6.3	18.5
15	2.590	19.0	52.9	2.317	144.6	6.0	18.2

SAMPLE SGSt59.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.076	9.5	22.3	1.955	122.0	20.7	31.0
1	2.920			2.059	128.5	16.4	27.4
2	2.840			2.117	132.1	14.1	25.3
3	2.781			2.162	134.9	12.5	23.7
4	2.752			2.185	136.3	11.3	22.9
5	2.726	21.0	55.6	2.206	137.6	10.5	22.2
6	2.709			2.219	138.5	9.9	21.7
7	2.691			2.234	139.4	9.5	21.2
8	2.675			2.246	140.3	8.8	20.7
9	2.661			2.259	141.0	8.3	20.3
10	2.649	21.0	57.2	2.270	141.6	7.9	19.9
11	2.639			2.278	142.2	7.5	19.6
12	2.629			2.287	142.7	7.2	19.3
13	2.62			2.295	143.2	6.9	19.0
14	2.612			2.302	143.6	6.6	18.8
15	2.603	21.0	58.2	2.308	144.0	6.3	18.6

SAMPLE SGSt59.11

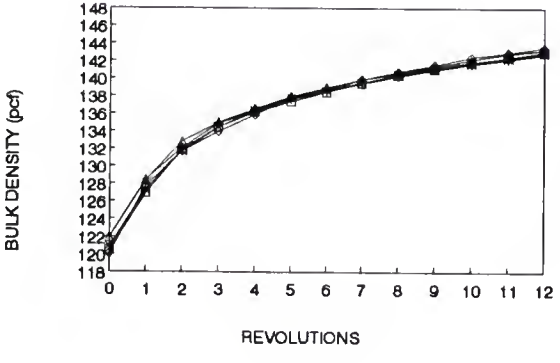
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.101	9.5	22.1	1.924	120.0	21.9	32.1
1	2.915			2.047	127.7	16.9	27.8
2	2.826			2.111	131.7	14.3	25.5
3	2.779			2.147	134.0	12.9	24.3
4	2.740			2.177	135.9	11.6	23.2
5	2.701	19.0	50.8	2.209	137.8	10.4	22.1
6	2.683			2.224	138.7	9.8	21.5
7	2.662			2.241	139.8	9.0	20.9
8	2.648			2.253	140.7	8.5	20.4
9	2.630			2.268	141.5	7.9	20.0
10	2.614	19.0	52.4	2.282	142.4	7.4	19.5
11	2.604			2.291	143.0	7.0	19.2
12	2.594			2.300	143.5	6.7	18.9
13	2.584			2.309	144.1	6.3	18.5
14	2.576			2.316	144.5	6.0	18.3
15	2.567	20.0	56.2	2.324	145.0	5.7	18.0

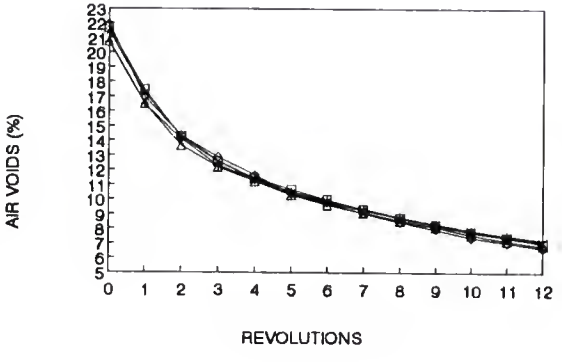
SAMPLE SGSt59.14

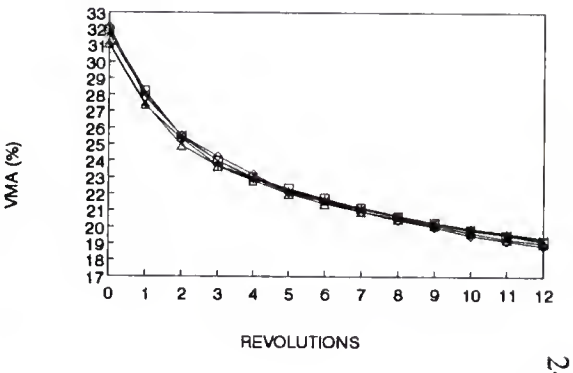
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.057	9.5	22.4	1.953	121.9	20.7	31.1
1	2.902			2.056	128.4	16.5	27.4
2	2.806			2.126	132.6	13.6	24.9
3	2.760			2.164	135.0	12.2	23.7
4	2.729			2.188	136.5	11.2	22.8
5	2.701	20.0	53.4	2.211	138.0	10.3	22.0
6	2.681			2.227	139.0	9.6	21.4
7	2.665			2.241	139.8	9.1	20.9
8	2.650			2.253	140.6	8.5	20.5
9	2.637			2.264	141.3	8.1	20.1
10	2.622	20.0	55.0	2.277	142.1	7.6	19.6
11	2.610			2.286	142.6	7.1	19.3
12	2.601			2.296	143.3	6.6	19.0
13	2.592			2.304	143.8	6.5	18.7
14	2.583			2.312	144.3	6.2	18.4
15	2.575	20.0	56.0	2.319	144.7	5.9	18.2

SAMPLE SGSt59.15

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.076	9.5	22.5	1.937	120.9	21.4	31.6
1	2.923			2.040	127.3	17.2	28.0
2	2.825			2.111	131.7	14.5	25.5
3	2.768			2.154	134.4	12.6	24.0
4	2.730			2.184	136.3	11.4	22.9
5	2.701	19.5	52.1	2.206	137.6	10.4	22.1
6	2.684			2.222	138.6	9.8	21.6
7	2.667			2.236	139.5	9.3	21.1
8	2.652			2.248	140.3	8.7	20.7
9	2.639			2.260	141.0	8.3	20.3
10	2.626	19.5	53.6	2.271	141.7	7.8	19.9
11	2.615			2.280	142.3	7.5	19.5
12	2.605			2.289	142.8	7.1	19.2
13	2.595			2.298	143.4	6.7	18.9
14	2.586			2.306	143.9	6.4	18.6
15	2.576	19.5	54.6	2.313	144.3	6.1	18.4







MIX ID: MT. VIEW (GA4)

GTM DENSIFICATION

RICE:	2.464	BSGcomp	2.315
BSG(Agg)	2.667	HTcomp	2.583
BINDER %	5.9	REVcomp	15

SAMPLE SGSt59.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.542	9.5	27.0	2.352	146.8	4.5	17.0
5	2.518	19.0	54.4	2.360	147.3	4.2	16.7
10	2.504	19.4	55.9	2.364	147.5	4.0	16.6
15	2.494	19.5	56.4	2.367	147.7	3.9	16.5
25	2.480	19.4	56.4	2.372	148.0	3.7	16.3
35	2.469	19.0	55.5	2.375	148.2	3.6	16.2
50	2.459	18.5	54.5	2.378	148.4	3.5	16.1
75	2.445	18.0	53.1	2.383	148.7	3.3	15.9
100	2.435	17.2	51.0	2.386	148.9	3.2	15.8
125	2.427	17.0	50.5	2.388	149.0	3.1	15.7
150	2.420	17.0	50.7	2.391	149.2	3.0	15.6
175	2.412	17.0	50.9	2.393	149.3	2.9	15.6
200	2.406	16.9	50.7	2.395	149.5	2.8	15.5
225	2.401	16.5	49.6	2.397	149.6	2.7	15.4
250	2.395	16.5	49.7	2.399	149.7	2.7	15.4
300	2.384	16.5	49.9	2.402	149.9	2.5	15.3

SAMPLE SGSt59.13

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.586	9.6	26.8	2.312	144.3	6.2	16.4
5	2.572	19.0	53.3	2.327	145.2	5.6	17.9
10	2.564	19.5	54.9	2.335	145.7	5.2	17.6
15	2.559	19.6	55.3	2.341	146.1	5.0	17.4
25	2.551	19.0	53.7	2.349	146.6	4.7	17.1
35	2.545	19.0	53.9	2.355	147.0	4.4	16.9
50	2.539	19.0	54.0	2.362	147.4	4.2	16.7
75	2.531	18.7	53.5	2.370	147.9	3.8	16.4
100	2.525	19.0	54.3	2.376	148.3	3.6	16.2
125	2.520	19.0	54.4	2.382	148.6	3.3	16.0
150	2.515	18.6	53.4	2.387	148.9	3.1	15.8
175	2.512	18.5	53.1	2.390	149.1	3.0	15.7
200	2.508	18.2	52.4	2.394	149.4	2.8	15.5
225	2.503	18.0	51.9	2.399	149.7	2.6	15.3
250	2.500	18.0	52.0	2.403	149.9	2.5	15.2
300	2.491	17.0	49.2	2.412	150.5	2.1	14.9

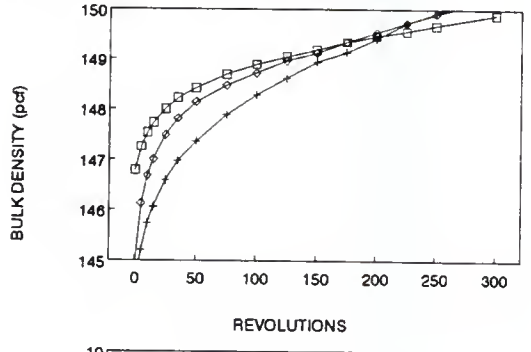
SAMPLE SGSt59.6

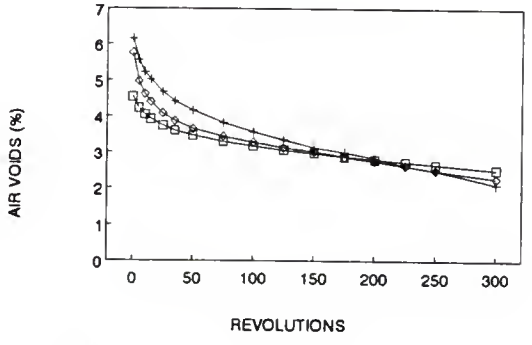
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.575	10.3	28.9	2.322	144.9	5.6	18.1
5	2.530	19.5	55.6	2.342	146.1	5.0	17.4
10	2.510	20.3	58.4	2.351	146.7	4.6	17.1
15	2.496	20.3	58.6	2.356	147.0	4.4	16.9
25	2.480	20.0	58.2	2.364	147.5	4.1	16.6
35	2.468	20.5	59.9	2.369	147.8	3.9	16.4
50	2.455	20.5	60.2	2.374	148.1	3.7	16.2
75	2.444	20.0	59.1	2.379	148.5	3.4	16.1
100	2.435	19.0	56.3	2.383	148.7	3.3	15.9
125	2.426	19.0	56.5	2.387	149.0	3.1	15.8
150	2.420	18.5	55.2	2.390	149.1	3.0	15.7
175	2.412	18.0	53.9	2.393	149.3	2.9	15.6
200	2.405	17.5	52.5	2.396	149.5	2.8	15.5
225	2.398	16.5	49.7	2.399	149.7	2.6	15.3
250	2.391	16.2	48.9	2.402	149.9	2.5	15.2
300	2.378	16.0	48.6	2.406	150.3	2.3	15.0

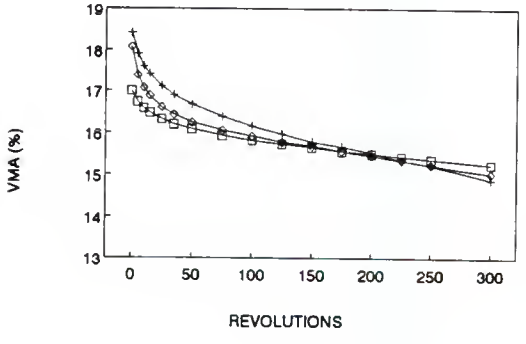
AVERAGE

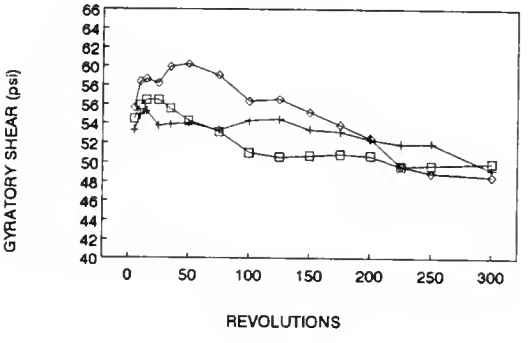
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	28.9	2.332	145.5	5.3	94.7	17.7
5	53.9	2.343	146.2	4.9	95.1	17.5
10	55.4	2.350	146.6	4.6	95.4	17.1
15	55.6	2.354	146.9	4.5	95.5	16.9
25	55.1	2.360	147.3	4.2	95.8	16.7
35	54.7	2.366	147.6	4.0	96.0	16.5
50	54.1	2.370	147.9	3.8	96.2	16.4
75	53.2	2.376	148.3	3.6	96.4	16.2
100	52.6	2.381	148.6	3.4	96.6	16.0
125	52.5	2.385	148.8	3.2	96.8	15.8
150	52.0	2.389	149.1	3.1	96.9	15.7
175	52.0	2.392	149.2	2.9	97.1	15.6
200	51.5	2.396	149.4	2.8	97.2	15.5
225	50.7	2.398	149.6	2.7	97.3	15.4
250	50.6	2.401	149.8	2.6	97.4	15.3
300	49.8	2.407	150.2	2.3	97.7	15.1

MIX ID: MT. VIEW (COMPACTED TO FIELD DENSITY)









MIX ID: WISCONSIN, I94 (WI1)

GTM COMPACTION

RICE: 2.6
BSG(Agg) 2.771
BINDER % 5.5

SAMPLE SWiVe35.2

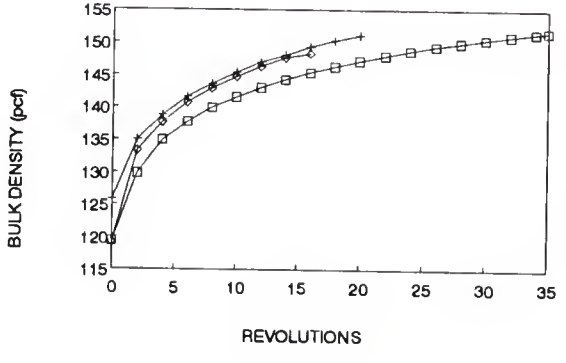
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.252	9.5	21.1	1.912	119.3	23.4	34.8
2	2.991			2.079	129.7	16.7	29.1
4	2.878	20.0	50.2	2.162	134.9	13.3	26.3
6	2.818			2.207	137.7	11.6	24.7
8	2.774			2.242	139.9	10.2	23.6
10	2.742	20.0	52.6	2.268	141.5	9.1	22.7
12	2.714			2.291	143.0	8.2	21.9
14	2.690	19.7	52.6	2.312	144.2	7.3	21.2
16	2.670			2.329	145.3	6.7	20.6
18	2.653	19.5	53.0	2.344	146.3	6.1	20.1
20	2.637	19.0	52.0	2.358	147.1	5.5	19.6
22	2.623			2.371	147.9	5.0	19.2
24	2.610	19.0	52.3	2.383	148.7	4.5	18.7
26	2.598			2.394	149.4	4.1	18.4
28	2.589			2.402	149.9	3.7	18.1
30	2.579	18.7	52.3	2.411	150.5	3.4	17.8
32	2.570			2.420	151.0	3.0	17.5
34	2.562			2.427	151.5	2.7	17.2
35	2.559	18.3	52.2	2.430	151.6	2.6	17.1

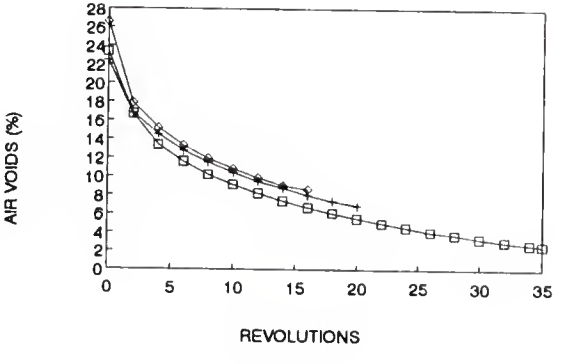
SAMPLE SWiVe35.7

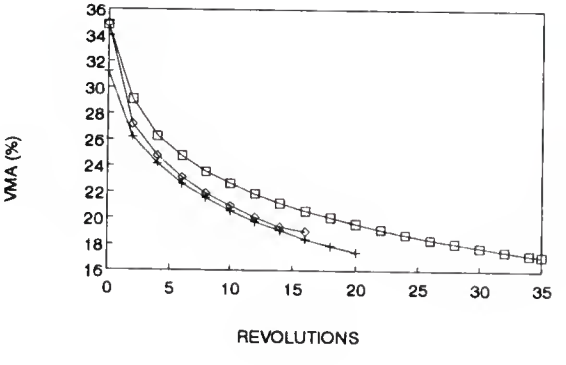
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.131	11.0	23.4	2.017	125.8	22.4	31.2
2	2.918	18.0	44.5	2.164	135.0	16.8	26.2
4	2.840	18.3	46.5	2.223	138.7	14.5	24.2
6	2.783	18.0	49.3	2.269	141.6	12.7	22.8
8	2.744	18.9	49.7	2.301	143.6	11.5	21.9
10	2.710	18.9	50.3	2.330	145.4	10.4	20.9
12	2.682	18.9	50.9	2.354	146.9	9.5	19.7
14	2.661	18.9	51.3	2.373	148.1	8.7	19.1
16	2.636	19.0	52.0	2.393	149.3	8.0	18.4
18	2.622	19.0	52.3	2.406	150.3	7.4	17.9
20	2.607	18.7	51.8	2.422	151.1	6.8	17.4

SwiVe35.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.331	9.0	19.4	1.909	119.1	26.6	34.9
2	2.996	17.3	41.7	2.136	133.3	17.9	27.2
4	2.901	17.8	44.3	2.208	137.8	15.2	24.8
6	2.838	18.3	47.0	2.255	140.7	13.3	23.1
8	2.794	18.5	47.8	2.290	142.9	11.9	21.9
10	2.760	18.3	47.8	2.318	144.7	10.8	20.9
12	2.730	18.8	49.7	2.344	146.3	9.9	20.1
14	2.705	18.5	49.4	2.363	147.5	9.0	19.3
15	2.693	18.5	49.6	2.378	148.3	8.6	19.0







MIX ID. WISCONSIN, I-94 (WI1)

GTM COMPACTION

RICE: 2.6
BSG(Agg) 2.771
BINDER % 5.5

SAMPLE SWIVe55.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.131	11.0	25.4	2.017	125.8	22.4	31.2
2	2.916	16.0	44.5	2.164	135.0	15.6	26.2
4	2.840	18.5	46.5	2.223	138.7	14.5	24.2
6	2.783	19.0	49.3	2.269	141.6	12.7	22.6
8	2.744	18.9	49.7	2.301	143.6	11.5	21.3
10	2.710	18.9	50.5	2.330	145.4	10.4	20.5
12	2.682	18.9	50.9	2.354	146.9	9.5	19.7
14	2.661	18.9	51.3	2.373	148.1	8.7	19.1
16	2.639	19.0	52.0	2.393	149.3	8.0	18.4
18	2.622	19.0	52.3	2.408	150.3	7.4	17.9
20	2.607	18.7	51.6	2.422	151.1	6.6	17.4

SAMPLE SWIVe55.8

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.116	9.5	22.0	2.024	126.3	22.2	31.0
1	3.008			2.089	131.0	19.3	28.4
2	2.913			2.166	135.2	16.7	26.1
3	2.860			2.206	137.7	15.1	24.6
4	2.821			2.237	139.6	14.0	23.7
5	2.790	19.0	49.1	2.262	141.1	13.0	22.9
6	2.770			2.276	142.1	12.4	22.3
7	2.750			2.294	143.2	11.6	21.6
8	2.731			2.310	144.2	11.1	21.2
9	2.715			2.324	145.0	10.6	20.7
10	2.700	19.5	52.1	2.337	145.8	10.1	20.3
11	2.688			2.347	146.5	9.7	19.9
12	2.677			2.357	147.1	9.3	19.6
13	2.668			2.365	147.6	9.0	19.3
14	2.659			2.373	148.1	8.7	19.1
15	2.651	19.5	53.1	2.380	148.5	8.5	18.8
16	2.643			2.387	149.0	8.2	18.6
17	2.636			2.394	149.4	7.9	18.4
18	2.629			2.400	149.8	7.7	18.1
19	2.622			2.406	150.2	7.4	17.9
20	2.616	19.5	53.6	2.412	150.5	7.2	17.7

SAMPLE SWIVe55.9

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.202	10.0	22.5	1.982	123.7	23.8	32.4
1	3.080			2.061	128.6	20.7	29.7
2	2.969			2.136	133.4	17.8	27.1
3	2.908			2.183	136.2	16.1	25.6
4	2.865			2.215	138.2	14.8	24.5
5	2.843	16.6	47.7	2.232	139.5	14.1	23.9
6	2.810			2.259	140.9	13.1	23.0
7	2.785			2.279	142.2	12.3	22.3
8	2.765			2.295	143.2	11.7	21.7
9	2.748			2.310	144.1	11.2	21.2
10	2.733	19.2	50.7	2.322	144.9	10.7	20.8
11	2.720			2.333	145.6	10.3	20.4
12	2.708			2.344	146.2	9.9	20.1
13	2.697			2.353	146.8	9.3	19.7
14	2.688			2.361	147.3	9.2	19.5
15	2.678	19.2	51.7	2.370	147.9	8.8	19.2
16	2.67			2.377	148.3	8.6	18.9
17	2.662			2.384	148.8	8.3	18.7
18	2.654			2.391	149.2	8.0	18.4
19	2.647			2.398	149.6	7.8	18.2
20	2.639	19.2	52.5	2.405	150.1	7.5	18.0

SAMPLE SWIVe55.11

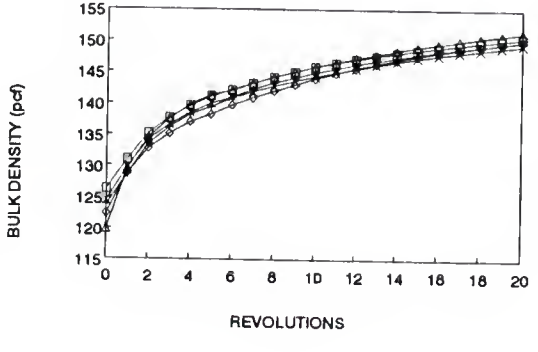
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.212	10.0	22.5	1.960	122.3	24.5	33.2
1	3.050			2.064	128.8	20.6	29.6
2	2.950			2.127	132.7	18.2	27.5
3	2.908			2.155	136.1	16.7	26.2
4	2.868			2.195	137.0	15.6	25.1
5	2.843	19.0	46.2	2.215	138.2	14.8	24.5
6	2.813			2.238	139.7	13.9	23.7
7	2.789			2.257	140.9	13.2	23.0
8	2.766			2.275	141.9	12.5	22.4
9	2.746			2.291	143.0	11.9	21.9
10	2.729	19.0	50.2	2.307	144.0	11.3	21.3
11	2.713			2.321	144.8	10.7	20.9
12	2.698			2.334	145.6	10.2	20.4
13	2.685			2.345	146.5	9.8	20.0
14	2.675			2.355	147.0	9.4	19.7
15	2.662	19.0	51.5	2.365	147.6	9.0	19.3
16	2.651			2.375	148.2	8.7	19.0
17	2.642			2.383	148.7	8.3	18.7
18	2.633			2.391	149.2	8.0	18.5
19	2.626			2.398	149.6	7.8	18.2
20	2.619	19.0	52.3	2.404	150.0	7.5	18.0

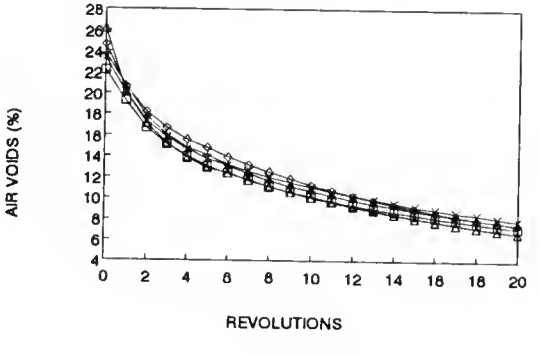
SAMPLE SWIVe55.13

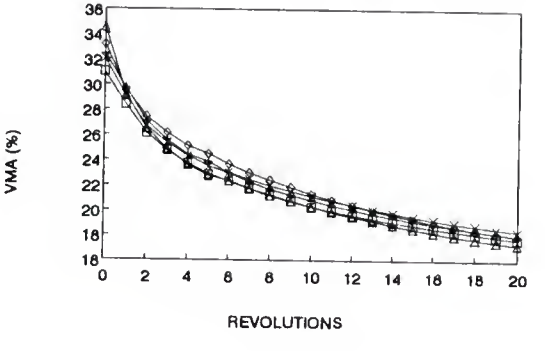
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.279	9.5	20.3	1.921	119.8	28.1	34.5
1	3.033			2.076	129.6	20.1	29.2
2	2.922			2.155	134.5	17.1	26.5
3	2.856			2.204	137.5	15.2	24.9
4	2.812			2.240	139.8	13.9	23.8
5	2.781	18.3	48.0	2.265	141.3	12.9	22.8
6	2.756			2.277	142.1	12.4	22.4
7	2.744			2.295	143.2	11.7	21.7
8	2.725			2.311	144.2	11.1	21.2
9	2.709			2.325	145.1	10.6	20.7
10	2.694	19.0	50.9	2.338	145.9	10.1	20.3
11	2.681			2.349	146.6	9.7	19.9
12	2.669			2.360	147.2	9.2	19.5
13	2.658			2.369	147.8	8.9	19.2
14	2.647			2.379	148.5	8.5	18.9
15	2.637	19.0	52.0	2.388	149.0	8.1	18.6
16	2.628			2.396	149.5	7.8	18.3
17	2.619			2.405	150.0	7.5	18.0
18	2.611			2.412	150.5	7.2	17.7
19	2.604			2.418	150.9	7.0	17.5
20	2.597	19.0	52.6	2.425	151.3	6.7	17.3

SAMPLE SWIVe55.14

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.185	10.5	23.9	1.994	124.4	23.3	32.0
1	3.036			2.079	129.7	20.1	29.1
2	2.935			2.150	134.2	17.5	26.7
3	2.864			2.198	136.5	15.8	25.4
4	2.844			2.219	136.5	14.7	24.5
5	2.813	19.0	46.7	2.243	140.0	13.7	23.5
6	2.795			2.258	140.9	13.2	23.0
7	2.778			2.273	141.9	12.6	22.5
8	2.758			2.288	142.8	12.0	22.0
9	2.743			2.301	143.6	11.5	21.5
10	2.729	20.0	52.9	2.312	144.3	11.1	21.1
11	2.716			2.323	145.0	10.6	20.6
12	2.705			2.333	145.6	10.3	20.4
13	2.693			2.343	146.2	9.9	20.1
14	2.684			2.351	146.7	9.6	19.8
15	2.674	20.0	54.0	2.360	147.3	9.2	19.5
16	2.666			2.367	147.7	9.0	19.3
17	2.658			2.374	148.1	8.7	19.0
18	2.651			2.380	148.5	8.4	18.8
19	2.643			2.386	149.0	8.2	18.6
20	2.636	20.0	54.7	2.394	149.4	7.9	18.4







MIX ID: WISCONSIN, I94 (W11) GTM DENSIFICATION

RICE:	2.6	BSGcomp	2.41
BSG(Agg)	2.771	HTcomp	2.619
BINDER %	5.5	REVcomp	20

SAMPLE SWIVe55.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.628	19.5	26.6	2.402	149.9	7.6	18.1
5	2.566	18.0	50.2	2.419	150.9	7.0	17.5
10	2.567	18.5	52.0	2.426	151.4	6.7	17.3
15	2.562	18.5	52.3	2.432	151.8	6.5	17.1
25	2.550	18.0	51.3	2.441	152.3	6.1	16.8
35	2.512	18.2	52.3	2.448	152.8	5.8	16.5
50	2.491	18.5	53.6	2.456	153.3	5.5	16.2
75	2.487	18.5	54.1	2.466	153.9	5.2	15.9
100	2.451	18.0	55.0	2.472	154.3	4.9	15.7
125	2.437	18.0	55.3	2.478	154.6	4.7	15.5
150	2.425	18.0	55.6	2.483	154.9	4.5	15.3
175	2.417	18.0	55.7	2.486	155.1	4.4	15.2
200	2.408	17.9	50.9	2.490	155.4	4.2	15.1
225	2.400	17.5	52.0	2.493	155.6	4.1	15.0
250	2.393	17.0	51.3	2.496	155.7	4.0	14.9
300	2.382	16.5	50.0	2.500	156.0	3.8	14.7

SAMPLE SWIVe55.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.600	19.8	30.0	2.428	151.5	6.9	17.2
5	2.575	18.0	50.4	2.437	152.1	6.3	16.9
10	2.557	18.5	52.2	2.443	152.5	6.0	16.7
15	2.545	18.5	52.5	2.448	152.7	5.9	16.5
25	2.524	18.5	52.9	2.455	153.2	5.6	16.3
35	2.506	18.5	53.3	2.462	153.6	5.3	16.0
50	2.485	18.2	52.8	2.469	154.1	5.0	15.8
75	2.458	18.0	52.8	2.479	154.7	4.6	15.4
100	2.448	17.5	51.9	2.483	154.9	4.5	15.3
125	2.423	17.5	52.1	2.492	155.5	4.2	15.0
150	2.410	17.0	50.9	2.497	155.8	4.0	14.9
175	2.400	17.0	51.1	2.500	156.0	3.8	14.7
200	2.391	16.5	49.8	2.504	156.2	3.7	14.6
225	2.384	16.5	49.9	2.506	156.4	3.6	14.5
250	2.378	16.0	48.8	2.508	156.5	3.5	14.5
300	2.368	15.5	47.2	2.512	156.7	3.4	14.3

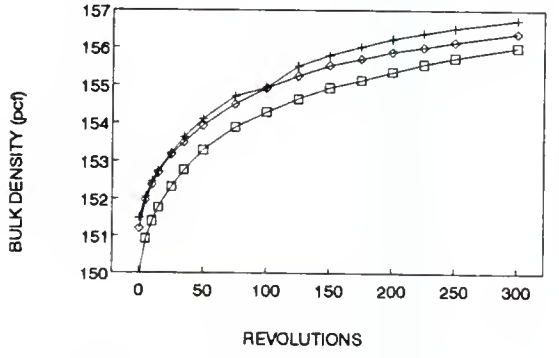
SAMPLE SWIVe55.15

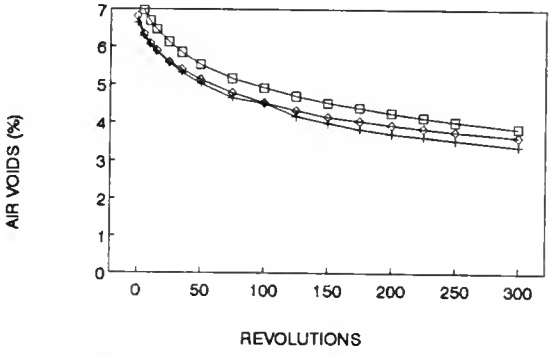
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.605	10.0	27.7	2.423	151.2	6.6	17.4
5	2.570	17.0	47.7	2.435	152.0	6.3	17.0
10	2.551	17.5	49.5	2.442	152.4	6.1	16.7
15	2.537	17.8	50.6	2.447	152.7	5.9	16.6
25	2.515	17.8	51.1	2.454	153.2	5.6	16.3
35	2.500	18.0	52.0	2.460	153.5	5.4	16.1
50	2.480	18.0	52.4	2.467	153.9	5.1	15.9
75	2.454	18.2	53.5	2.476	154.5	4.8	15.6
100	2.435	18.2	53.9	2.483	154.9	4.5	15.3
125	2.420	18.0	53.7	2.488	155.2	4.3	15.2
150	2.407	17.5	52.5	2.492	155.5	4.1	15.0
175	2.399	17.9	51.1	2.495	155.7	4.0	14.9
200	2.391	17.0	51.3	2.498	155.9	3.9	14.8
225	2.385	16.8	50.8	2.500	156.0	3.8	14.7
250	2.379	16.5	50.0	2.502	156.1	3.8	14.7
300	2.368	16.5	50.3	2.506	156.4	3.6	14.5

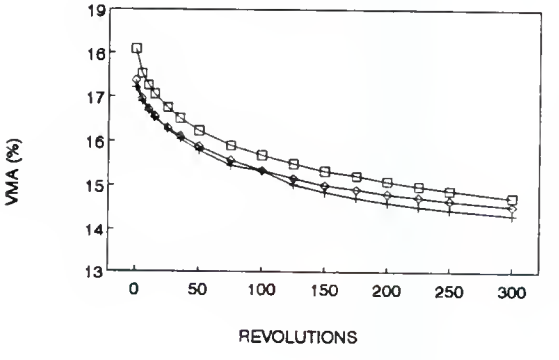
AVERAGE

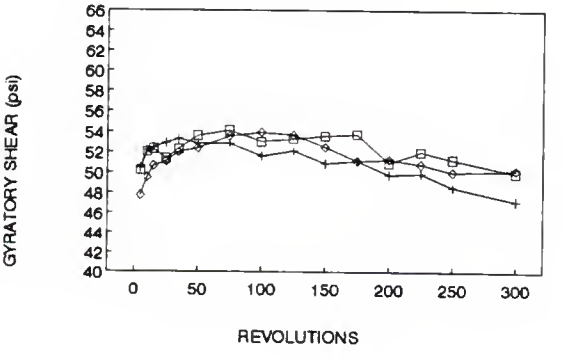
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	29.4	2.415	150.7	7.1	92.9	17.7
5	50.3	2.428	151.5	6.6	93.4	17.2
10	52.1	2.435	151.9	6.4	93.6	17.0
15	52.4	2.440	152.2	6.2	93.8	16.8
25	52.1	2.448	152.8	5.8	94.2	16.5
35	52.6	2.455	153.2	5.6	94.4	16.3
50	53.2	2.463	153.7	5.3	94.7	16.0
75	53.5	2.473	154.3	4.9	95.1	15.7
100	52.3	2.478	154.6	4.7	95.3	15.5
125	52.7	2.485	155.1	4.4	95.6	15.3
150	52.2	2.490	155.4	4.2	95.8	15.1
175	52.4	2.493	155.6	4.1	95.9	15.0
200	50.4	2.497	155.8	4.0	96.0	14.9
225	51.0	2.499	156.0	3.9	96.1	14.8
250	49.9	2.502	156.1	3.8	96.2	14.7
300	48.6	2.506	156.4	3.6	96.4	14.5

MIX ID: W74 (COMPACTED TO FIELD DENSITY)









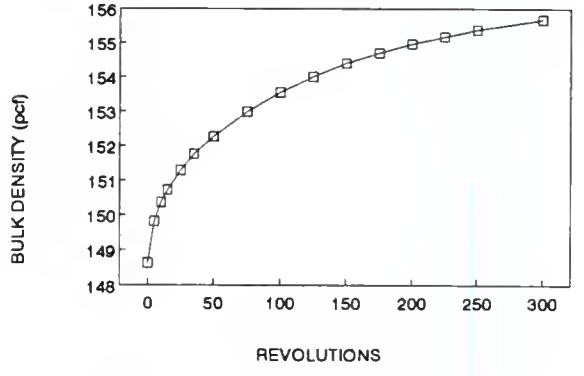
MIX ID: WISCONSIN, I94 GTM DENSIFICATION

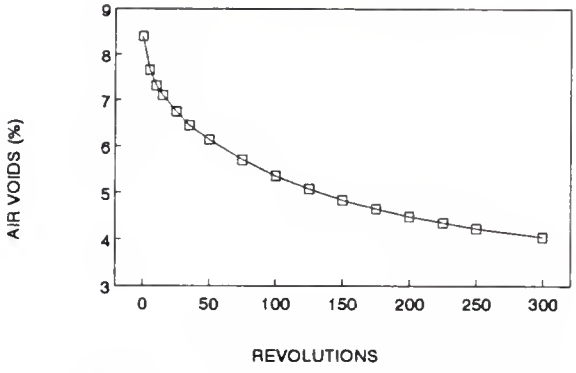
RICE:	2.6	BSGcomp	2.41	
BSG(Agg)	2.771	HTcomp	2.619	densification checking only!
BINDER %	5.5	REVcomp	20	

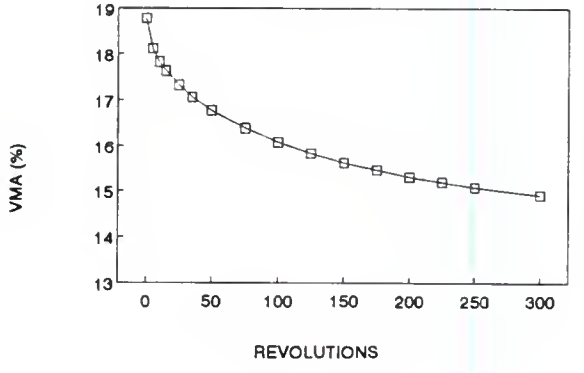
SAMPLE SWIVe55.16 densification checking one sample only!

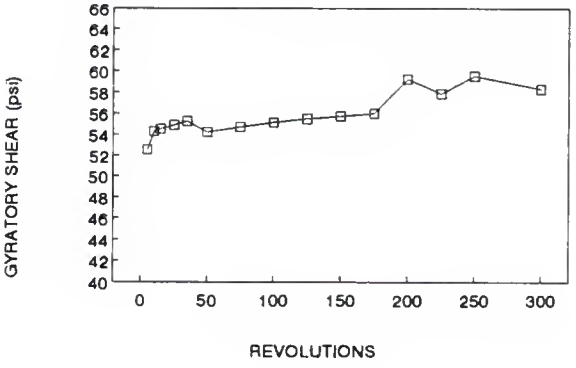
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.650	11.5	31.3	2.382	148.6	8.4	18.8
5	2.610	19.0	52.5	2.401	149.8	7.7	18.1
10	2.592	19.5	54.3	2.410	150.4	7.3	17.8
15	2.580	19.5	54.5	2.415	150.7	7.1	17.6
25	2.561	19.5	54.9	2.424	151.3	6.8	17.3
35	2.545	19.5	55.3	2.432	151.8	6.5	17.1
50	2.528	19.0	54.2	2.440	152.3	6.1	16.8
75	2.504	19.0	54.8	2.452	153.0	5.7	16.4
100	2.485	19.0	55.2	2.461	153.6	5.3	16.1
125	2.470	19.0	55.5	2.468	154.0	5.1	15.8
150	2.457	19.0	55.8	2.474	154.4	4.8	15.6
175	2.447	19.0	56.0	2.479	154.7	4.6	15.5
200	2.438	20.0	56.2	2.483	155.0	4.5	15.3
225	2.431	19.5	57.9	2.487	155.2	4.4	15.2
250	2.424	20.0	58.5	2.490	155.4	4.2	15.1
300	2.414	19.5	58.3	2.495	155.7	4.0	14.9

MIX ID: W74 (COMPACTED TO FIELD DENSITY)









MIX ID: WISCONSIN, I43 (WI2)

GTM COMPACTION

RICE: 2.53
BSG(Agg) 2.707
BINDER % 5.5

SAMPLE SW4355.5

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.097	9.0	21.0	2.000	124.8	21.0	30.2
1	2.975			2.062	129.9	17.7	27.3
2	2.870			2.156	134.6	14.7	24.7
3	2.805			2.208	137.8	12.7	22.9
4	2.761			2.243	140.0	11.3	21.7
5	2.722	18.6	49.6	2.275	142.0	10.1	20.6

SAMPLE SW4355.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.078	10.0	23.4	1.999	124.8	21.0	30.2
1	2.950			2.066	130.2	17.5	27.2
2	2.845			2.163	135.0	14.5	24.5
3	2.782			2.212	138.0	12.6	22.8
4	2.743			2.242	139.9	11.4	21.7
5	2.710	19.0	50.6	2.271	141.7	10.2	20.7

SAMPLE SW4355.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.066	11.0	23.7	2.015	125.8	20.4	29.7
1	2.960			2.099	131.0	17.0	26.7
2	2.865			2.169	135.3	14.3	24.3
3	2.800			2.219	138.5	12.3	22.5
4	2.756			2.253	140.6	11.0	21.4
5	2.724	18.5	49.0	2.281	142.3	9.9	20.4

SAMPLE SW4355.13

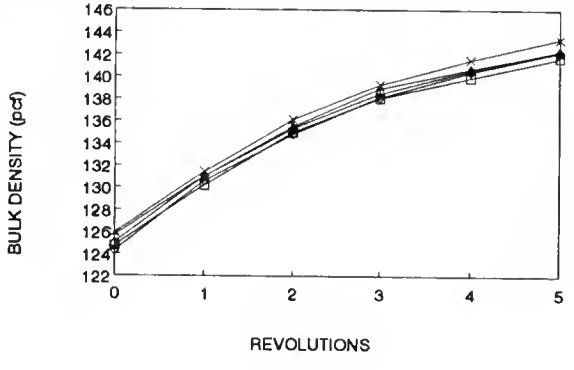
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.078	10.0	23.4	1.992	124.3	21.3	30.3
1	2.930			2.092	130.6	17.3	27.0
2	2.838			2.160	134.8	14.6	24.8
3	2.770			2.213	138.1	12.5	22.7
4	2.725			2.250	140.4	11.1	21.5
5	2.699	12.0	32.2	2.280	142.3	9.9	20.4

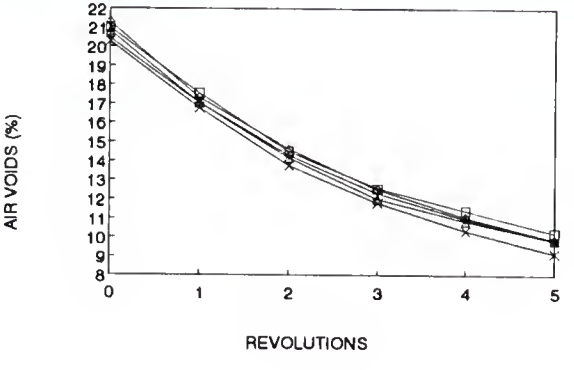
SAMPLE SW4355.8

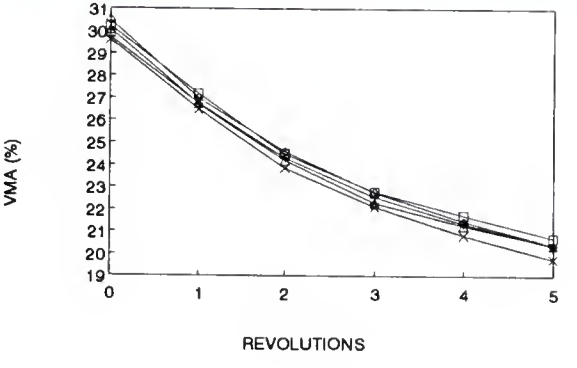
REV	HT	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.105	10.8	25.1	2.004	125.0	20.8	30.0
1	2.964			2.099	131.0	17.0	26.7
2	2.863			2.172	135.5	14.2	24.2
3	2.795			2.226	138.9	12.0	22.3
4	2.759			2.255	140.7	10.9	21.3
5	2.729	19.5	51.6	2.280	142.3	9.9	20.4

SAMPLE SW4355.9

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.101	11.6	27.5	2.017	125.9	20.3	29.6
1	2.970			2.106	131.4	18.8	28.3
2	2.867			2.182	136.1	13.9	23.8
3	2.803			2.232	139.3	11.9	22.1
4	2.758			2.266	141.5	10.4	20.9
5	2.722	19.0	50.4	2.296	143.4	9.2	19.8







MIX ID: WISCONSIN, I 43 (WI2)

GTM COMPACTION

RICE: 2.509
BSG(Agg) 2.707
BINDER % 5 5

SAMPLE SW4355 4

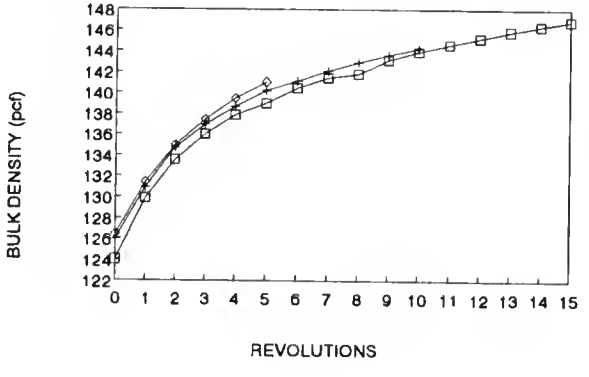
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3 210	8 5	19.1	1.987	124.0	20 6	30 6
1	3 065			2.061	129.9	17.0	27.3
2	2 980			2.141	133.6	14.7	25.3
3	2.926			2.180	136 0	13.1	23 9
4	2 888			2 209	137 6	12.0	22.9
5	2.864	19 5	49 1	2.227	139 0	11.2	22.2
6	2 835			2.250	140.4	10 3	21 4
7	2 815			2.266	141 4	9 7	20 9
8	2.807			2.273	141 6	9.4	20 7
9	2.781			2.294	143.1	8 6	19.9
10	2.766	19.0	49 6	2.306	143.9	8.1	19.5
11	2.753			2.317	144.6	7 6	19 1
12	2.741			2.327	145.2	7 2	18 8
13	2.729			2.338	145.9	6 6	18.4
14	2.719			2.346	146 4	6 S	18.1
15	2.710	19.0	50.6	2.354	146 9	6.2	17.8

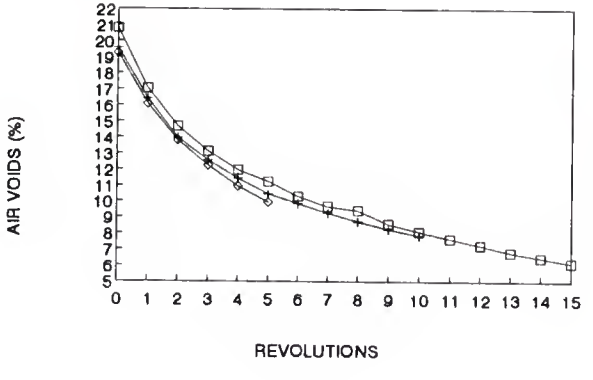
SAMPLE SW4355 3

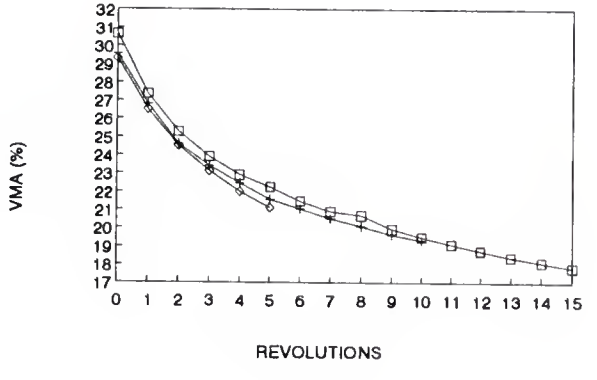
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.196	8.0	18.1	2.016	125 9	19 8	29 5
1	3 075			2.098	130 9	16.4	26 8
2	2 987			2.160	134 8	13.9	24 6
3	2 940			2.194	136 9	12 6	23 4
4	2.903			2.222	138.7	11.4	22 4
5	2.871	20.0	50 3	2.247	140.2	10 5	21 6
6	2.852			2 262	141.1	9 9	21.0
7	2.833			2.277	142.1	9 3	20.5
8	2.817			2.290	142 9	8.7	20.1
9	2.802			2.302	143.7	8.2	19.6
10	2.790	20.5	53 0	2.312	144.3	7.9	19.3

SAMPLE SW4355.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.168	8 5	19.4	2.026	126 4	19 3	29.3
1	3 048			2.106	131 4	16.1	26 5
2	2 967			2.163	135.0	13 8	24 5
3	2.914			2 203	137.4	12 2	23.1
4	2.872			2.235	139 5	10 9	22.0
5	2.840	19	48.3	2 260	141 0	9 9	21.1







MIX ID: WISCONSIN, I43 (WI2)

GTM DENSIFICATION

RICE:	2.53	BSGcomp	2.281
BSG(Agg)	2.707	HTcomp	2.716
BINDER %	5.5	REVcomp	5

SAMPLE SW4355.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.692	9.0	24.1	2.301	143.6	9.0	19.7
5	2.622	20.5	56.4	2.338	145.9	7.6	18.4
10	2.604	20.0	55.4	2.348	146.5	7.2	18.0
15	2.586	20.0	55.8	2.357	147.1	6.8	17.7
25	2.561	19.0	53.5	2.371	147.9	6.3	17.2
35	2.541	19.0	54.0	2.381	148.6	5.9	16.9
50	2.518	19.0	54.4	2.393	149.4	5.4	16.4
75	2.490	19.0	56.1	2.408	150.3	4.8	15.9
100	2.472	18.0	52.5	2.418	150.9	4.4	15.6
125	2.456	18.0	52.9	2.426	151.4	4.1	15.3
150	2.444	18.0	53.1	2.433	151.8	3.8	15.1
175	2.435	18.0	53.3	2.437	152.1	3.7	14.9
200	2.427	18.0	53.5	2.442	152.4	3.5	14.8
225	2.418	19.0	56.7	2.447	152.7	3.3	14.6
250	2.408	19.0	56.9	2.452	153.0	3.1	14.4
300	2.398	19.0	57.2	2.457	153.3	2.9	14.2

SAMPLE SW4355.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.545	9.0	25.5	2.434	151.9	3.8	15.0
5	2.504	16.0	51.9	2.444	152.5	3.4	14.7
10	2.493	18.5	53.5	2.446	152.6	3.3	14.6
15	2.483	19.0	55.2	2.448	152.8	3.2	14.5
25	2.469	19.0	55.5	2.452	153.0	3.1	14.4
35	2.458	19.0	56.8	2.454	153.1	3.0	14.3
50	2.445	19.0	56.1	2.457	153.3	2.9	14.2
75	2.429	19.0	56.4	2.461	153.5	2.7	14.1
100	2.416	19.0	56.7	2.463	153.7	2.6	14.0
125	2.409	19.0	56.9	2.465	153.8	2.6	13.9
150	2.402	19.0	57.1	2.467	153.9	2.5	13.9
175	2.393	19.0	57.3	2.469	154.1	2.4	13.8
200	2.386	19.0	57.5	2.470	154.2	2.4	13.8
225	2.379	19.0	57.6	2.472	154.3	2.3	13.7
250	2.378	19.0	57.7	2.473	154.3	2.3	13.7
300	2.366	19.0	57.9	2.475	154.4	2.2	13.6

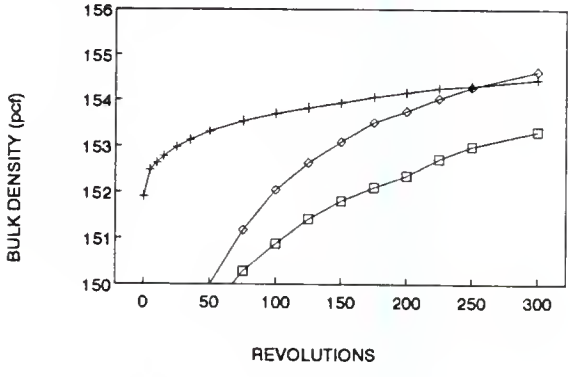
SAMPLE SW4355.10

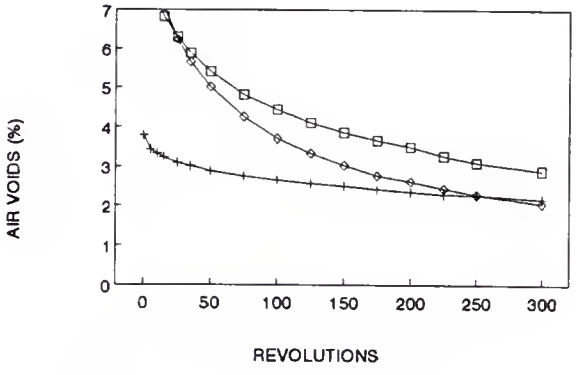
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.715	10.5	27.9	2.282	142.4	9.8	20.3
5	2.632	18.5	50.7	2.328	145.3	8.0	18.7
10	2.612	19.0	52.5	2.340	146.0	7.5	18.3
15	2.590	19.0	52.9	2.352	146.8	7.0	17.9
25	2.553	19.0	53.7	2.373	148.1	6.2	17.2
35	2.527	19.0	54.3	2.387	149.0	5.6	16.7
50	2.496	19.0	54.9	2.403	150.0	5.0	16.1
75	2.464	18.5	54.2	2.423	151.2	4.2	15.4
100	2.439	19.0	56.2	2.437	152.0	3.7	14.9
125	2.422	19.0	56.6	2.446	152.6	3.3	14.6
150	2.409	19.0	56.9	2.453	153.1	3.0	14.4
175	2.397	19.0	57.2	2.460	153.5	2.8	14.1
200	2.39	18.5	55.9	2.464	153.8	2.6	14.0
225	2.382	18.5	56.0	2.468	154.0	2.4	13.8
250	2.375	19.0	57.7	2.472	154.3	2.3	13.7
300	2.365	19.0	58.0	2.478	154.8	2.1	13.5

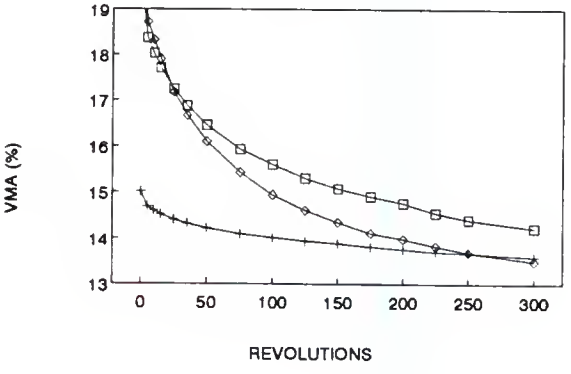
AVERAGE sample SW4355.7 OMITTED

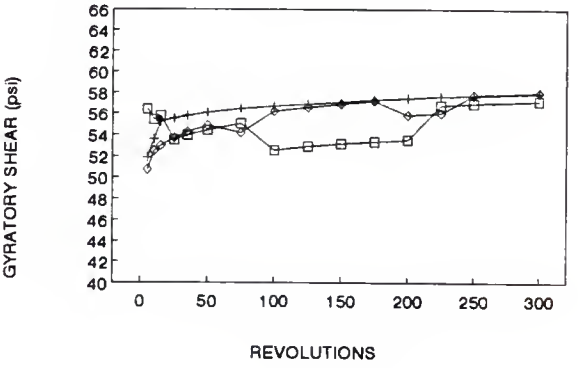
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	26.0	2.292	143.0	9.4	90.6	20.0
5	53.6	2.333	145.6	7.8	92.2	18.5
10	54.0	2.344	146.2	7.4	92.6	18.2
15	54.4	2.355	146.9	6.9	93.1	17.8
25	53.6	2.372	148.0	6.3	93.7	17.2
35	54.1	2.384	148.8	5.8	94.2	16.8
50	54.7	2.398	149.7	5.2	94.8	16.3
75	54.6	2.415	150.7	4.5	95.5	15.7
100	54.4	2.427	151.5	4.1	95.9	15.3
125	54.7	2.436	152.0	3.7	96.3	15.0
150	55.0	2.443	152.4	3.4	96.6	14.7
175	55.3	2.449	152.8	3.2	96.8	14.5
200	54.7	2.453	153.1	3.1	96.9	14.4
225	56.4	2.458	153.4	2.8	97.2	14.2
250	57.3	2.462	153.8	2.7	97.3	14.1
300	57.6	2.468	154.0	2.5	97.5	13.9

MIX ID: WISCONSIN, I43 (COMPACTED TO FIELD DENSITY)









MIX ID. WIS 126 (WI3)

GTM COMPACTION

RICE: 2.482
BSG(Agg) 2.66
BINDER % 6.2

SAMPLE WIS F.1

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.092	11	25.7	1.960	122.3	21.0	30.9
1	2.985			2.030	126.7	18.2	28.4
2	2.887			2.099	131.0	15.4	26.0
3	2.830			2.141	133.6	13.7	24.5
4	2.785			2.176	135.8	12.3	23.3
5	2.750	16.5	48.5	2.203	137.5	11.2	22.3
6	2.727			2.222	138.7	10.5	21.6
7	2.704			2.241	139.8	9.7	21.0
8	2.683			2.258	140.9	9.0	20.4
9	2.665			2.274	141.9	8.4	19.8
10	2.650	19	51.7	2.287	142.7	7.9	19.4
11	2.635			2.300	143.5	7.3	18.9
12	2.622	19	52.3	2.311	144.2	6.9	18.5

SAMPLE WIS F.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.143	9	20.7	1.931	120.5	22.2	31.9
1	3.010			2.016	125.8	18.8	28.9
2	2.905			2.089	130.3	15.8	26.3
3	2.825			2.148	134.0	13.5	24.3
4	2.777			2.185	136.3	12.0	23.0
5	2.742	19.5	51.3	2.213	138.1	10.8	22.0
6	2.718			2.232	139.3	10.1	21.3
7	2.693			2.253	140.6	9.2	20.5
8	2.672			2.271	141.7	8.5	19.9
9	2.653			2.287	142.7	7.9	19.3
10	2.635	20	54.8	2.303	143.7	7.2	18.8
11	2.621			2.315	144.5	6.7	18.4
12	2.612	20	55.3	2.323	145.0	6.4	18.1

SAMPLE WIS F.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.098	10	23.3	1.949	121.6	21.5	31.3
1	2.976			2.027	126.5	18.3	28.5
2	2.853			2.116	132.0	14.7	25.4
3	2.785			2.168	135.3	12.7	23.6
4	2.735			2.207	137.7	11.1	22.2
5	2.703	20	53.4	2.234	139.4	10.0	21.2
6	2.680			2.253	140.6	9.2	20.6
7	2.658			2.271	141.7	8.5	19.9
8	2.638			2.289	142.8	7.8	19.3
9	2.621			2.303	143.7	7.2	18.8
10	2.605	19.5	54.0	2.316	144.6	6.6	18.3
11	2.592			2.329	145.3	6.2	17.9
12	2.579	19.5	54.6	2.341	146.1	5.7	17.4

SAMPLE WIS F.4

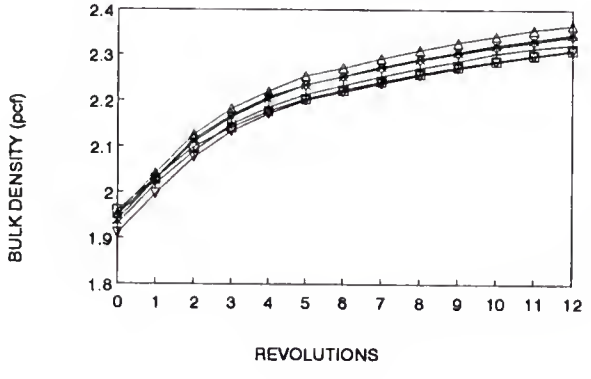
REV	HT	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.092	9	21.0	1.951	121.8	21.4	31.2
1	2.956			2.041	127.4	17.8	28.0
2	2.839			2.125	132.6	14.4	25.1
3	2.766			2.181	136.1	12.1	23.1
4	2.717			2.221	138.6	10.5	21.7
5	2.677	19.5	52.6	2.254	140.6	9.2	20.5
6	2.656			2.272	141.7	8.5	19.9
7	2.632			2.292	143.0	7.6	19.2
8	2.611			2.311	144.2	6.9	18.5
9	2.593			2.327	145.2	6.3	18.0
10	2.576	20	56.0	2.342	146.1	5.6	17.4
11	2.562			2.355	146.9	5.1	17.0
12	2.550	20	56.6	2.366	147.6	4.7	16.6

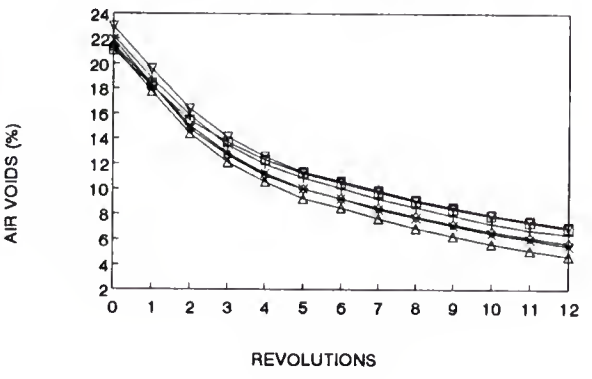
SAMPLE WIS F.5

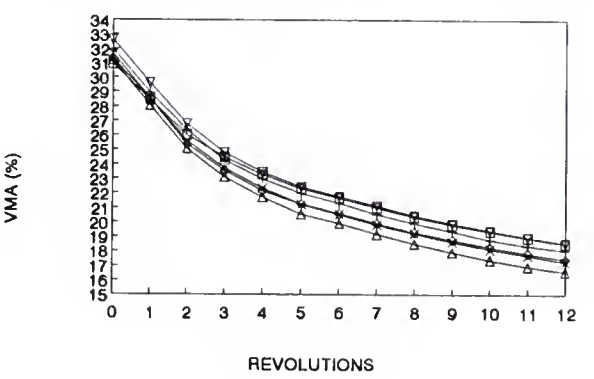
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.116	9	20.6	1.939	121.0	21.9	31.6
1	2.980			2.027	126.5	18.3	28.5
2	2.863			2.110	131.7	15.0	25.6
3	2.792			2.164	135.0	12.6	23.7
4	2.742			2.203	137.5	11.2	22.3
5	2.704	20.5	54.7	2.234	139.4	10.0	21.2
6	2.681			2.253	140.6	9.2	20.5
7	2.657			2.274	141.9	8.4	19.8
8	2.637			2.291	142.9	7.7	19.2
9	2.619			2.307	143.9	7.1	18.7
10	2.602	20	55.5	2.322	144.9	6.5	18.1
11	2.589			2.333	145.6	6.0	17.7
12	2.575	20	56.0	2.346	146.4	5.5	17.3

SAMPLE WIS F.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.158	9	20.6	1.911	119.3	23.0	32.6
1	3.024			1.996	124.5	19.6	29.6
2	2.907			2.076	129.6	16.3	26.8
3	2.831			2.132	133.0	14.1	24.8
4	2.781			2.170	135.4	12.6	23.5
5	2.743	20	52.6	2.200	137.3	11.3	22.4
6	2.720			2.219	138.5	10.6	21.8
7	2.698			2.237	139.6	9.9	21.1
8	2.676			2.256	140.7	9.1	20.5
9	2.658			2.271	141.7	8.5	19.9
10	2.641	19.5	53.3	2.285	142.6	7.9	19.4
11	2.627			2.298	143.4	7.4	19.0
12	2.614	19.5	53.8	2.309	144.1	7.0	18.6







MIX ID: WIS 126 (WIS) GTM DENSIFICATION

RICE:	2.462	BSGcomp	2.333
BSG(Agg)	2.66	HTcomp	2.592
BINDER %	6.2	REVcomp	15

SAMPLE wis126.110

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.700	10.0	26.7	2.240	139.6	9.6	21.0
5	2.657	17.5	47.5	2.267	141.5	8.7	20.1
10	2.638	18.0	49.3	2.281	142.3	8.1	19.6
15	2.619	18.0	49.6	2.292	143.0	7.7	19.2
25	2.591	18.0	50.1	2.309	144.1	7.0	18.6
35	2.570	18.0	50.5	2.323	144.9	6.4	18.1
50	2.545	18.0	51.0	2.339	145.9	5.8	17.5
75	2.514	18.0	51.7	2.359	147.2	5.0	16.8
100	2.489	18.0	52.2	2.375	148.2	4.3	16.3
125	2.469	18.0	52.6	2.388	149.0	3.8	15.8
150	2.453	18.0	53.0	2.398	149.6	3.4	15.4
175	2.440	18.0	53.2	2.406	150.1	3.1	15.2
200	2.429	18.0	53.5	2.413	150.6	2.8	14.9
225	2.419	18.0	53.7	2.420	151.0	2.5	14.7
250	2.411	18.0	53.9	2.425	151.3	2.3	14.5
300	2.398	18.0	54.2	2.433	151.8	2.0	14.2

SAMPLE wis126.111

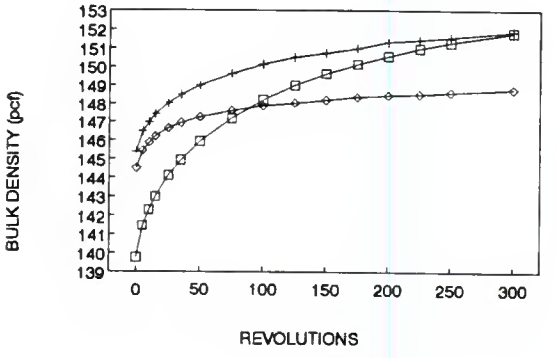
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.595	10.0	27.6	2.330	145.4	6.1	17.6
5	2.537	18.5	52.2	2.348	146.5	5.4	17.2
10	2.539	18.5	52.6	2.356	147.0	5.1	16.9
15	2.524	18.5	52.9	2.362	147.4	4.8	16.7
25	2.503	18.5	53.3	2.372	148.0	4.4	16.4
35	2.487	18.5	53.7	2.379	148.5	4.1	16.1
50	2.469	18.5	54.1	2.387	149.0	3.8	15.8
75	2.446	18.5	54.6	2.398	149.6	3.4	15.4
100	2.428	18.5	55.0	2.406	150.1	3.1	15.2
125	2.415	18.5	55.3	2.412	150.5	2.8	15.0
150	2.406	18.5	55.5	2.416	150.8	2.7	14.8
175	2.397	18.5	55.7	2.420	151.0	2.5	14.7
200	2.388	18.5	55.9	2.425	151.3	2.3	14.5
225	2.382	18.5	56.0	2.427	151.4	2.2	14.4
250	2.377	18.5	56.2	2.429	151.6	2.1	14.3
300	2.366	18.5	56.4	2.434	151.9	1.9	14.2

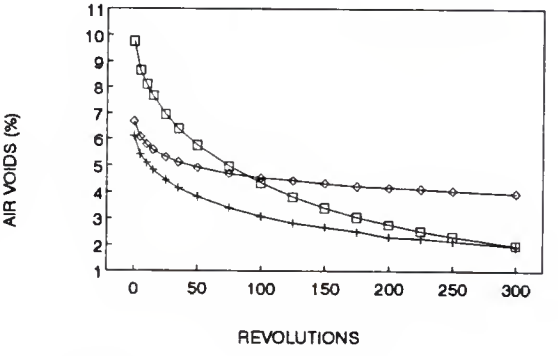
SAMPLE wis126.112

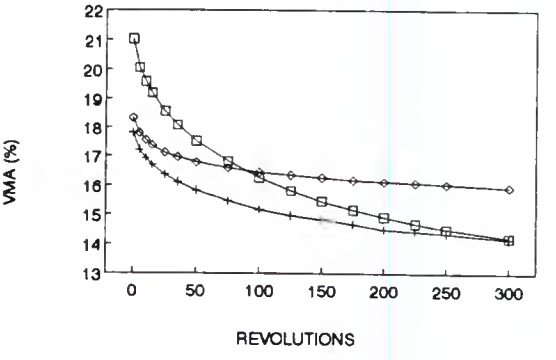
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.611	10.0	27.6	2.316	144.5	6.7	18.3
5	2.582	17.5	48.9	2.331	145.4	6.1	17.8
10	2.566	18.5	52.0	2.336	145.9	5.8	17.6
15	2.556	18.5	52.2	2.343	146.2	5.6	17.4
25	2.544	18.5	52.5	2.350	146.7	5.3	17.1
35	2.535	18.5	52.7	2.355	146.9	5.1	17.0
50	2.525	19.0	54.3	2.360	147.3	4.9	16.8
75	2.514	19.0	54.5	2.366	147.6	4.7	16.6
100	2.506	19.0	54.7	2.370	147.9	4.5	16.4
125	2.501	19.0	54.8	2.372	148.0	4.4	16.3
150	2.496	19.0	54.9	2.375	148.2	4.3	16.3
175	2.491	19.5	56.5	2.377	148.3	4.2	16.2
200	2.486	20.0	58.0	2.379	148.4	4.2	16.1
225	2.486	20.0	58.1	2.380	148.5	4.1	16.1
250	2.483	20.0	58.1	2.381	148.6	4.1	16.0
300	2.478	20.0	58.2	2.384	148.8	3.9	15.9

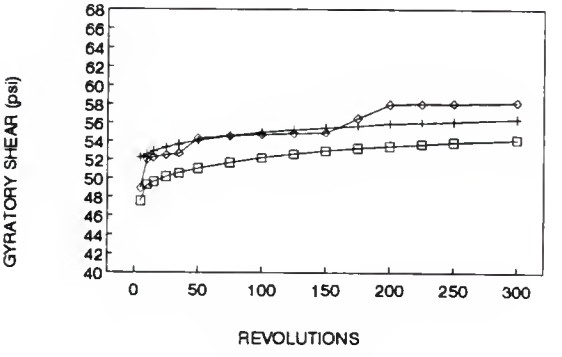
AVERAGE

REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	27.4	2.295	143.2	7.5	92.5	19.1
5	49.5	2.315	144.5	6.7	93.3	18.4
10	51.3	2.325	145.1	6.3	93.7	18.0
15	51.8	2.332	145.5	6.0	94.0	17.8
25	52.0	2.344	146.3	5.6	94.4	17.3
35	52.3	2.352	146.8	5.2	94.8	17.0
50	53.1	2.362	147.4	4.8	95.2	16.7
75	53.6	2.374	148.1	4.3	95.7	16.3
100	54.0	2.383	148.7	4.0	96.0	16.0
125	54.2	2.391	149.2	3.7	96.3	15.7
150	54.5	2.396	149.5	3.5	96.5	15.5
175	55.1	2.401	149.8	3.3	96.7	15.3
200	55.6	2.406	150.1	3.1	96.9	15.2
225	55.9	2.409	150.3	3.0	97.0	15.1
250	56.1	2.412	150.5	2.8	97.2	15.0
300	56.3	2.417	150.8	2.6	97.4	14.8









MIX ID: WIS207 (WI4)

GTM COMPACTION

RICE: 2.841
BSG(Agg) 2.73
BINDER % 5.9

SAMPLE WIS207.101

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.000	0	21.8	2.084	130.0	18.0	26.2
1	2.906			2.131	134.2	15.3	23.6
2	2.828			2.210	137.9	13.0	23.5
3	2.782			2.247	140.2	11.6	22.5
4	2.749			2.274	141.9	10.5	21.6
5	2.722	19.3	51.7	2.297	143.3	9.6	20.8
6	2.702			2.314	144.4	9.0	20.3
7	2.685			2.326	145.3	8.4	19.7
8	2.669			2.342	146.2	7.8	19.3
9	2.654			2.353	147.0	7.3	18.8
10	2.644	20	54.6	2.364	147.5	7.0	18.5
11	2.631	20	54.9	2.376	148.3	6.5	18.1

SAMPLE WIS207.102

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.185	0	20.4	1.994	124.4	21.5	31.3
1	3.062			2.074	129.4	18.4	28.3
2	2.964			2.142	133.7	13.7	26.2
3	2.900			2.190	136.6	13.8	24.9
4	2.853			2.224	138.8	12.5	23.9
5	2.813	17	43.6	2.257	140.9	11.2	22.2
6	2.787			2.279	142.2	10.3	21.5
7	2.762			2.296	143.3	9.5	20.7
8	2.741			2.317	144.6	8.8	20.1
9	2.720			2.335	145.7	8.1	19.5
10	2.701	17	43.4	2.351	146.7	7.5	19.0
11	2.684	17	43.7	2.366	147.6	6.9	18.4

SAMPLE WIS207.103

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.111	0	20.9	2.006	125.3	21.0	30.6
1	2.993			2.087	130.2	17.9	28.1
2	2.906			2.150	134.1	15.4	25.9
3	2.846			2.195	137.0	13.6	24.3
4	2.801			2.230	139.2	12.2	23.1
5	2.757	13	39.3	2.266	141.4	10.8	21.9
6	2.732			2.287	142.7	10.0	21.2
7	2.706			2.309	144.1	9.1	20.4
8	2.684			2.327	145.2	8.4	19.8
9	2.663			2.346	146.4	7.7	19.1
10	2.643	13	41.0	2.364	147.5	7.0	18.5
11	2.627	13	41.2	2.376	148.4	6.4	18.0

SAMPLE WIS207.104

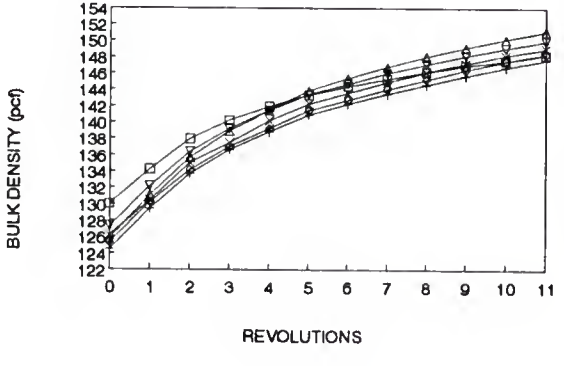
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.103	0	20.9	2.016	125.8	20.7	30.5
1	2.979			2.100	131.0	17.4	27.6
2	2.878			2.174	135.6	14.9	25.1
3	2.811			2.226	138.9	12.4	23.3
4	2.760			2.267	141.4	10.8	21.9
5	2.714	11.5	30.6	2.305	143.8	9.3	20.5
6	2.683			2.330	145.4	8.3	19.7
7	2.660			2.352	146.8	7.4	18.9
8	2.637			2.372	148.0	6.6	18.2
9	2.618			2.390	149.1	6.0	17.6
10	2.600	11.3	31.9	2.406	150.1	5.3	17.1
11	2.583	11.5	32.1	2.422	151.1	4.7	16.5

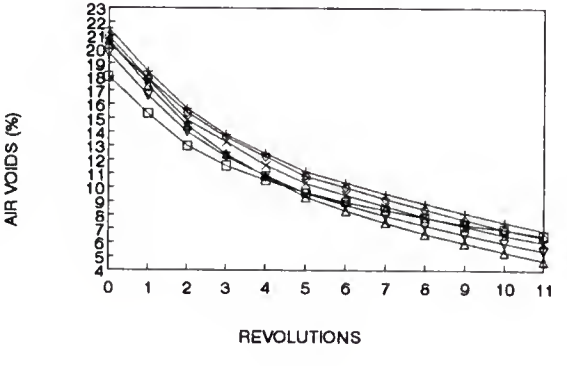
SAMPLE WIS207.105

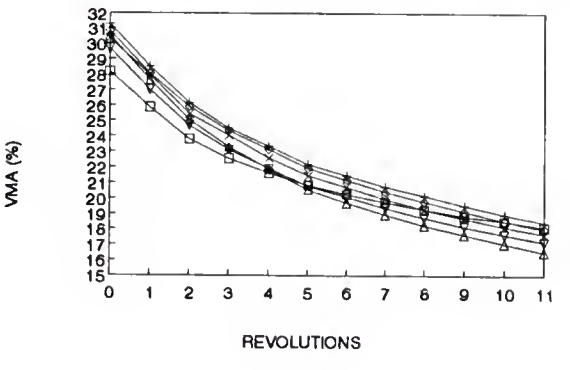
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.110	0	20.9	2.022	126.2	20.4	30.3
1	3.006			2.090	130.4	17.7	27.9
2	2.906			2.164	135.0	14.8	25.4
3	2.854			2.203	137.5	13.3	24.1
4	2.799			2.246	140.2	11.6	22.6
5	2.756	15.5	40.5	2.279	142.2	10.3	21.4
6	2.733			2.301	143.6	9.5	20.7
7	2.706			2.322	144.9	8.6	20.0
8	2.685			2.342	146.1	7.8	19.3
9	2.666			2.356	147.2	7.2	18.7
10	2.648	16	43.6	2.374	146.2	6.6	18.2
11	2.633	16	43.8	2.386	149.0	6.0	17.7

SAMPLE WIS207.106

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.110	0	20.9	2.040	127.3	19.7	29.7
1	2.993			2.116	132.2	16.6	27.0
2	2.903			2.185	136.4	14.0	24.7
3	2.844			2.231	139.2	12.2	23.1
4	2.800			2.266	141.4	10.8	21.9
5	2.761	13.3	40.5	2.296	143.4	9.6	20.8
6	2.736			2.316	144.7	8.7	20.1
7	2.712			2.336	146.0	7.9	19.4
8	2.691			2.357	147.1	7.2	18.7
9	2.672			2.374	148.2	6.6	18.2
10	2.655	13.3	42.1	2.389	149.1	6.0	17.6
11	2.640	16	43.7	2.403	149.9	5.4	17.2







MIX ID: WIS 207 (WI4)

GTM DENSIFICATION

RICE:	2.541	BSGcomp	2.389
BSG(Agg)	2.73	HTcomp	2.633
BINDER %	5.9	REVcomp	11

SAMPLE WIS 207.107

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.650	12.0	32.7	2.574	148.1	6.8	18.2
5	2.606	18.5	51.2	2.599	149.7	5.6	17.3
10	2.585	19.0	53.0	2.410	150.4	5.1	16.9
15	2.572	19.0	53.5	2.418	150.9	4.9	16.7
25	2.552	19.0	53.7	2.429	151.6	4.4	16.5
35	2.536	19.0	54.1	2.438	152.1	4.1	16.0
50	2.517	19.0	54.5	2.448	152.8	3.6	15.8
75	2.491	19.0	55.0	2.463	153.7	3.1	15.1
100	2.474	19.0	55.4	2.473	154.3	2.7	14.8
125	2.460	19.0	55.7	2.480	154.8	2.4	14.5
150	2.449	18.5	54.5	2.487	155.2	2.1	14.5
175	2.440	18.5	54.7	2.492	155.5	1.9	14.1
200	2.432	18.5	54.9	2.496	155.8	1.8	14.0
225	2.427	18.5	55.0	2.499	155.9	1.7	13.9
250	2.420	19.0	56.7	2.503	156.2	1.5	13.7
300	2.411	18.5	55.4	2.508	156.5	1.3	13.6

SAMPLE WIS 207.108

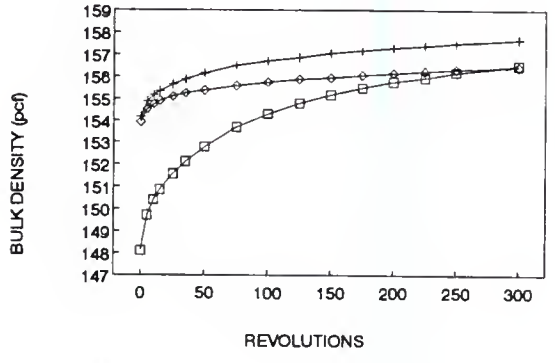
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.546	9.5	26.9	2.471	154.2	2.8	14.6
5	2.512	19.0	54.6	2.482	154.9	2.5	14.5
10	2.496	20.0	57.8	2.487	155.2	2.1	14.3
15	2.489	19.5	56.5	2.490	155.3	2.0	14.2
25	2.475	19.0	55.4	2.494	155.6	1.8	14.0
35	2.463	18.5	54.2	2.498	155.9	1.7	13.9
50	2.450	19.0	56.0	2.502	156.2	1.5	13.7
75	2.434	19.0	56.5	2.508	156.5	1.3	13.6
100	2.424	18.5	55.1	2.511	156.7	1.2	13.4
125	2.416	18.5	55.3	2.514	156.9	1.1	13.4
150	2.408	18.5	55.5	2.517	157.1	0.9	13.2
175	2.401	18.5	55.8	2.519	157.2	0.9	13.2
200	2.395	18.5	55.7	2.521	157.5	0.8	13.1
225	2.390	19.0	54.3	2.522	157.4	0.7	13.1
250	2.385	19.0	54.5	2.524	157.5	0.7	13.0
300	2.378	18.0	54.7	2.527	157.7	0.6	12.9

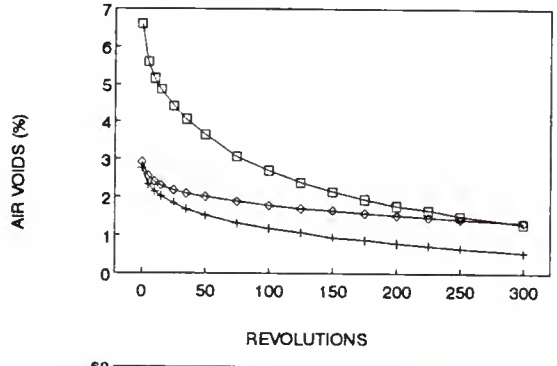
SAMPLE WIS 207.109

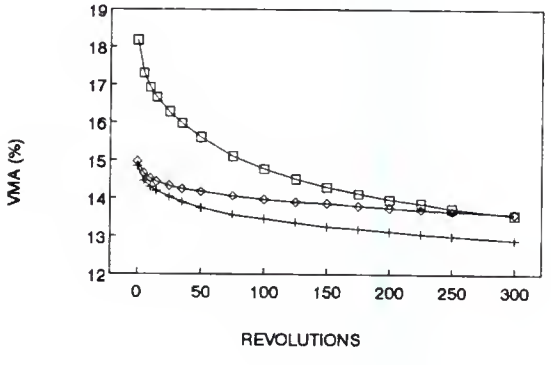
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.550	11.0	31.1	2.467	153.9	2.9	15.0
5	2.515	18.0	51.8	2.478	154.5	2.9	14.7
10	2.501	18.0	51.9	2.480	154.7	2.4	14.5
15	2.491	18.0	52.1	2.482	154.9	2.5	14.4
25	2.479	18.5	53.9	2.486	155.1	2.2	14.3
35	2.470	18.5	54.0	2.488	155.2	2.1	14.2
50	2.462	18.0	52.8	2.490	155.4	2.0	14.2
75	2.450	18.0	53.0	2.493	155.6	1.9	14.1
100	2.440	18.0	53.2	2.496	155.7	1.8	14.0
125	2.432	18.0	53.4	2.498	155.9	1.7	13.9
150	2.426	18.0	53.5	2.499	155.9	1.7	13.9
175	2.421	18.0	53.7	2.501	156.1	1.6	13.8
200	2.415	18.0	53.8	2.502	156.2	1.5	13.7
225	2.410	18.0	53.9	2.504	156.2	1.5	13.7
250	2.405	18.0	54.0	2.505	156.3	1.4	13.7
300	2.398	18.0	54.2	2.507	156.4	1.5	13.6

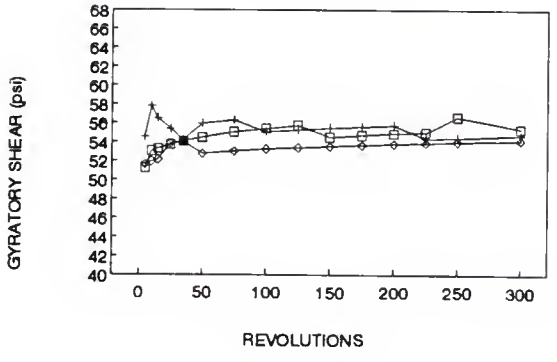
AVERAGE

REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	50.2	2.437	152.1	4.1	95.9	19.0
5	52.5	2.452	153.0	3.5	96.5	15.5
10	54.2	2.459	153.4	3.2	96.8	15.2
15	54.0	2.463	153.7	3.1	96.9	15.1
25	54.3	2.469	154.1	2.8	97.2	14.9
35	54.1	2.475	154.4	2.6	97.4	14.7
50	54.4	2.480	154.8	2.4	97.6	14.5
75	54.6	2.488	155.3	2.1	97.9	14.2
100	54.8	2.493	155.6	1.9	98.1	14.1
125	54.8	2.497	155.8	1.7	98.3	13.9
150	54.5	2.501	156.1	1.6	98.4	13.8
175	54.7	2.504	156.2	1.5	98.5	13.7
200	54.8	2.506	156.4	1.4	98.6	13.6
225	54.4	2.508	156.5	1.3	98.7	13.5
250	55.0	2.511	156.7	1.2	98.8	13.5
300	54.7	2.514	156.9	1.1	98.9	13.3









MIX ID: MARYLAND (MD1)

GTM COMPACTION

RICE: 2.626
BSG(Agg) 2.932
BINDER % 6.2

SAMPLE #1

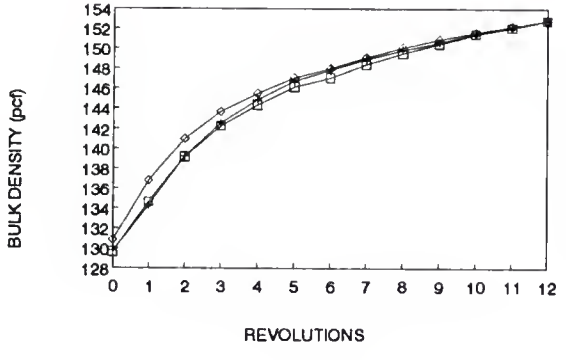
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.999	12	26.9	2.077	129.6	20.9	33.5
1	2.888			2.157	134.6	17.6	31.0
2	2.794			2.230	139.1	15.1	28.7
3	2.733			2.280	142.2	13.2	27.1
4	2.693			2.314	144.4	11.9	26.0
5	2.660	20.5	55.6	2.342	146.2	10.8	25.1
6	2.644			2.356	147.0	10.3	24.6
7	2.620			2.378	148.4	9.4	23.9
8	2.601			2.395	149.5	8.8	23.4
9	2.584			2.411	150.5	8.2	22.9
10	2.567	20	56.2	2.427	151.4	7.6	22.4
11	2.556			2.436	152.1	7.2	22.0
12	2.544	19	53.9	2.449	152.8	6.7	21.7

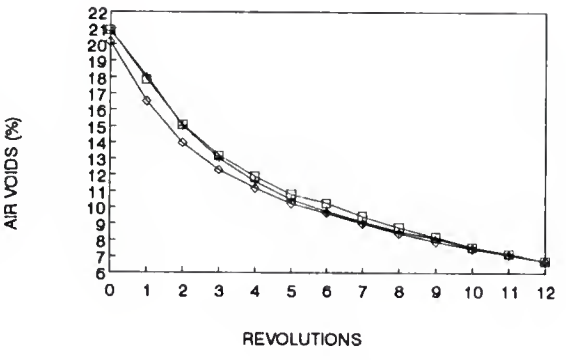
SAMPLE #2

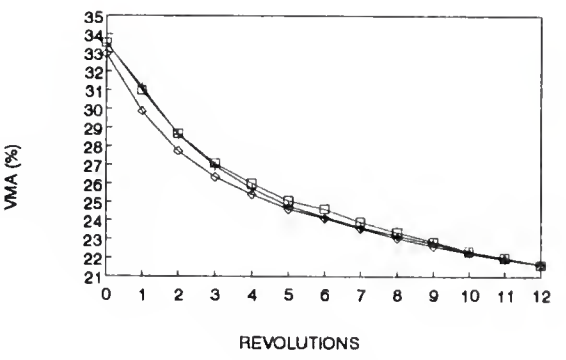
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.970	11.5	27.9	2.060	129.6	20.8	33.5
1	2.870			2.132	134.3	18.0	31.2
2	2.788			2.231	139.2	15.0	28.6
3	2.704			2.284	142.5	13.0	26.9
4	2.660			2.322	144.9	11.6	25.7
5	2.627	20	54.9	2.351	146.7	10.5	24.8
6	2.607			2.369	147.8	9.8	24.2
7	2.588			2.387	148.9	9.1	23.7
8	2.572			2.401	149.8	8.6	23.2
9	2.559			2.414	150.6	8.1	22.8
10	2.544	19.5	53.3	2.426	151.5	7.5	22.3
11	2.534			2.437	152.1	7.2	22.0
12	2.522	19.5	55.6	2.449	152.8	6.7	21.7

SAMPLE #3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.961	9.5	23.2	2.097	130.8	20.2	32.9
1	2.852			2.192	136.8	16.5	29.9
2	2.748			2.259	141.0	14.0	27.7
3	2.696			2.303	143.7	12.3	26.3
4	2.662			2.332	145.5	11.2	25.4
5	2.634	20	54.8	2.357	147.1	10.2	24.6
6	2.617			2.372	148.0	9.7	24.1
7	2.598			2.390	149.1	9.0	23.6
8	2.581			2.405	150.1	8.4	23.0
9	2.567			2.416	150.9	7.9	22.6
10	2.555	20	56.5	2.430	151.6	7.5	22.3
11	2.545			2.439	152.2	7.1	22.0
12	2.535	20	56.9	2.449	152.8	6.7	21.7







MIX ID: MARYLAND/SMV2

GTM COMPACTION

RICE: 2.626
BSG(Agg) 2.932
BINDER % 0.2

SAMPLE #4

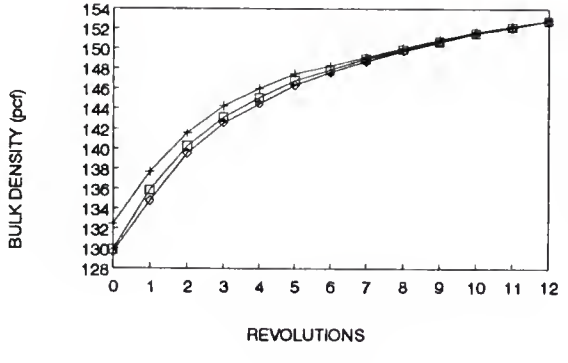
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.965	9.5	23.1	2.081	129.9	20.7	33.4
1	2.835			2.177	135.8	17.1	30.4
2	2.746			2.247	140.2	14.4	28.1
3	2.690			2.294	143.2	12.8	26.8
4	2.654			2.323	145.1	11.4	25.8
5	2.625	20.5	56.4	2.345	146.6	10.4	24.7
6	2.604			2.370	147.9	9.7	24.2
7	2.585			2.387	149.0	9.1	23.8
8	2.569			2.402	149.9	8.5	23.1
9	2.555			2.415	150.7	8.0	22.7
10	2.541	20	58.8	2.429	151.6	7.5	22.5
11	2.531			2.438	152.2	7.1	22.0
12	2.520	19.5	55.8	2.449	152.8	6.7	21.7

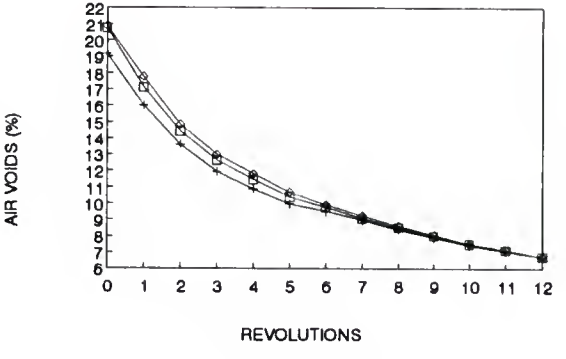
SAMPLE #5

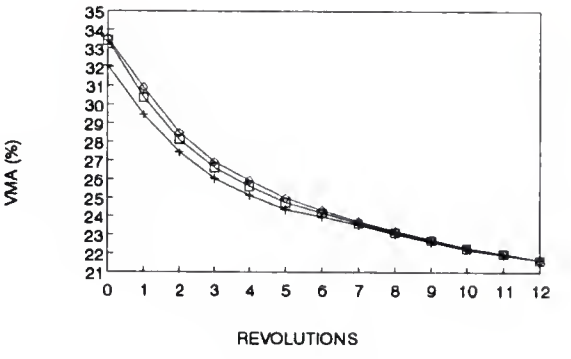
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.950	10	24.6	2.125	132.5	19.2	32.1
1	2.820			2.206	137.6	16.0	29.4
2	2.742			2.269	141.6	13.6	27.4
3	2.690			2.312	144.5	11.8	26.0
4	2.656			2.340	146.0	10.9	25.1
5	2.631	25	63.1	2.364	147.5	10.0	24.4
6	2.616			2.378	148.5	9.5	24.0
7	2.602			2.391	149.2	9.0	23.5
8	2.586			2.405	150.1	8.4	23.0
9	2.572			2.419	150.9	7.9	22.6
10	2.559	21.5	60.6	2.431	151.7	7.4	22.2
11	2.549			2.440	152.5	7.1	21.9
12	2.54	21.5	61.1	2.449	152.8	6.7	21.7

SAMPLE #6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.035	10.5	25.0	2.076	129.7	20.9	33.5
1	2.920			2.160	134.9	17.8	30.9
2	2.820			2.236	139.5	14.8	28.5
3	2.760			2.285	142.6	13.0	26.9
4	2.725			2.310	144.5	11.9	25.9
5	2.689	20.5	55.0	2.545	146.5	10.7	25.0
6	2.668			2.365	147.8	9.9	24.3
7	2.646			2.383	148.7	9.2	23.8
8	2.629			2.400	149.7	8.6	23.2
9	2.612			2.414	150.7	8.1	22.8
10	2.597	20.5	57.0	2.426	151.5	7.5	22.5
11	2.587			2.436	152.1	7.2	22.0
12	2.575	21	56.6	2.449	152.8	6.7	21.7







MIX ID: MARYLAND/SMV3

GTM COMPACTION

RICE: 2.626
BSG(Agg) 2.932
BINDER % 6.2

SAMPLE #7

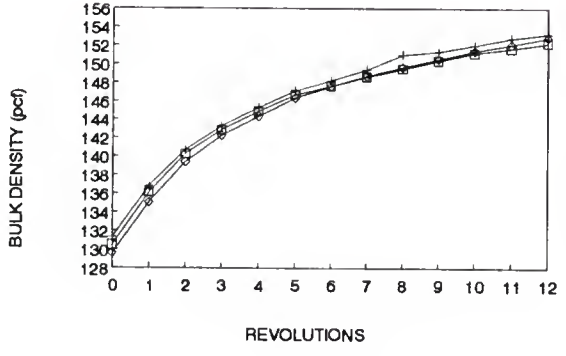
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.983	10	24.2	2.092	130.5	20.4	33.1
1	2.860			2.161	136.1	16.9	30.2
2	2.775			2.246	140.3	14.4	28.1
3	2.725			2.290	142.9	12.8	26.8
4	2.687			2.322	144.9	11.6	25.7
5	2.654	21.5	58.5	2.351	146.7	10.5	24.8
6	2.636			2.368	147.8	9.9	24.3
7	2.620			2.381	148.6	9.5	23.9
8	2.605			2.395	149.4	8.8	23.4
9	2.590			2.409	150.3	8.3	22.9
10	2.578	22	61.6	2.422	151.1	7.8	22.5
11	2.566			2.430	151.6	7.5	22.3
12	2.556	22	62.1	2.439	152.2	7.1	22.0

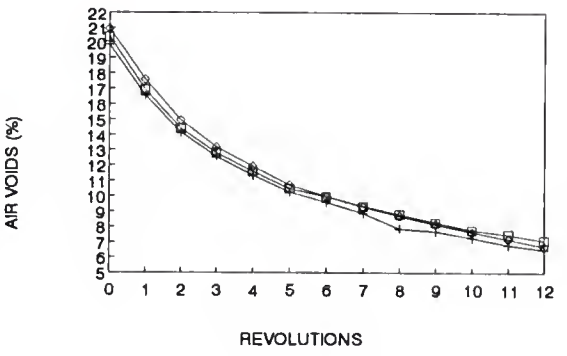
SAMPLE #8

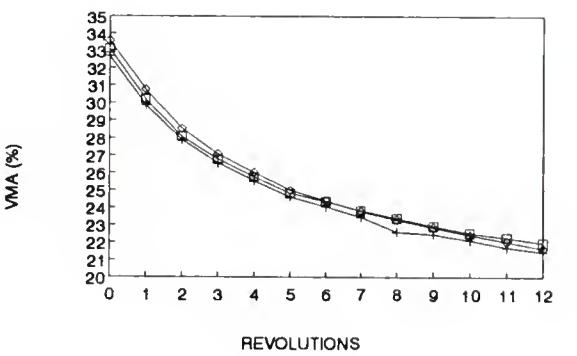
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	2.994	10.5	25.3	2.105	131.3	19.8	32.7
1	2.875			2.192	136.8	16.5	29.9
2	2.795			2.255	140.7	14.1	27.9
3	2.745			2.299	143.3	12.6	26.6
4	2.707			2.326	145.3	11.3	25.5
5	2.674	20.5	55.3	2.357	147.1	10.3	24.6
6	2.654			2.375	148.2	9.6	24.0
7	2.633			2.393	149.4	8.9	23.4
8	2.605			2.419	151.0	7.9	22.6
9	2.600			2.424	151.2	7.7	22.5
10	2.588	21.5	59.9	2.435	151.9	7.5	22.1
11	2.575			2.447	152.7	6.6	21.7
12	2.567	21.5	60.4	2.455	153.2	6.5	21.5

SAMPLE #9

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.027	10	23.6	2.077	129.6	20.9	33.6
1	2.905			2.164	135.0	17.6	30.6
2	2.814			2.234	139.4	14.9	28.5
3	2.756			2.279	142.2	13.2	27.1
4	2.716			2.313	144.3	11.9	26.0
5	2.681	21	56.5	2.345	146.3	10.7	25.0
6	2.659			2.364	147.5	10.0	24.4
7	2.639			2.382	148.6	9.3	23.8
8	2.622			2.398	149.6	8.7	23.3
9	2.607			2.411	150.5	8.2	22.9
10	2.592	20.5	57.1	2.425	151.3	7.8	22.4
11	2.580			2.437	152.0	7.2	22.0
12	2.567	20	56.2	2.449	152.8	6.7	21.7







MIX ID: MARYLAND (MD1)

GTM DENSIFICATION

RICE:	2.628	BSGcomp	2.449
BSG(Agg)	2.932	HTcomp	2.541
BINDER %	8.2	REVcomp	12

SAMPLE 2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.516	10.0	26.7	2.471	154.2	5.9	20.9
5	2.479	18.0	52.4	2.496	155.7	5.0	20.2
10	2.456	19.0	55.6	2.509	156.6	4.5	19.7
15	2.445	18.5	54.6	2.517	157.1	4.1	19.5
25	2.426	18.0	53.5	2.529	157.8	3.7	19.1
35	2.412	18.5	55.3	2.538	158.4	3.3	18.8
50	2.394	18.5	55.8	2.549	159.1	2.9	18.4
75	2.374	18.5	56.2	2.562	159.9	2.4	18.0
100	2.361	18.0	55.0	2.570	160.4	2.1	17.8
125	2.350	17.5	53.7	2.577	160.8	1.9	17.6
150	2.342	17.5	53.9	2.582	161.1	1.7	17.4
175	2.335	17.5	54.1	2.587	161.4	1.5	17.3
200	2.329	17.0	52.7	2.590	161.6	1.4	17.1
225	2.325	17.0	52.8	2.593	161.8	1.3	17.1
250	2.319	17.0	52.9	2.597	162.0	1.1	16.9
300	2.312	17.0	53.1	2.601	162.3	1.0	16.8

SAMPLE 3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.516	10.0	26.7	2.475	154.3	5.8	20.9
5	2.477	19.0	55.4	2.499	156.0	4.8	20.0
10	2.461	19.0	55.7	2.510	156.6	4.4	19.7
15	2.447	19.5	57.5	2.519	157.2	4.1	19.4
25	2.427	20.0	59.5	2.533	158.0	3.6	19.0
35	2.415	19.5	58.3	2.540	158.5	3.3	18.7
50	2.401	19.0	57.1	2.550	159.1	2.9	18.4
75	2.386	19.0	57.5	2.560	159.7	2.5	18.1
100	2.376	19.0	57.7	2.566	160.1	2.3	17.9
125	2.367	19.0	57.9	2.572	160.5	2.0	17.7
150	2.361	19.0	58.1	2.576	160.8	1.9	17.6
175	2.355	19.0	58.2	2.580	161.0	1.7	17.4
200	2.351	19.0	58.3	2.583	161.2	1.6	17.4
225	2.346	19.0	58.4	2.586	161.4	1.5	17.3
250	2.342	19.0	58.5	2.589	161.6	1.4	17.2
300	2.336	19.0	58.7	2.593	161.8	1.3	17.0

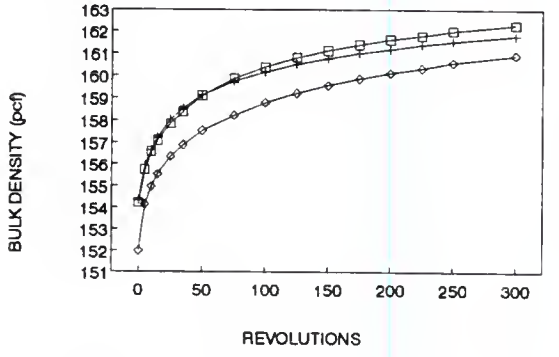
SAMPLE 9

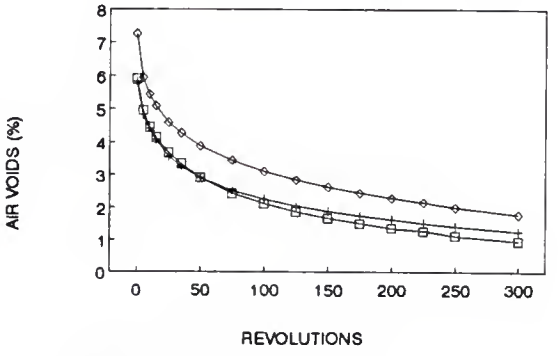
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.555	11.0	31.1	2.436	152.0	7.3	22.1
5	2.505	19.0	54.7	2.470	154.1	5.9	21.0
10	2.486	19.0	55.2	2.483	155.0	5.4	20.6
15	2.475	19.0	55.4	2.492	155.5	5.1	20.3
25	2.454	19.0	55.9	2.506	156.3	4.8	19.8
35	2.442	19.0	56.1	2.514	156.9	4.5	19.6
50	2.427	19.0	56.5	2.524	157.5	3.9	19.2
75	2.411	18.5	55.4	2.535	158.2	3.5	18.9
100	2.398	18.0	54.2	2.544	158.8	3.1	18.6
125	2.388	18.0	54.4	2.551	159.2	2.8	18.4
150	2.380	17.5	53.1	2.557	159.5	2.6	18.2
175	2.373	17.0	51.7	2.562	159.8	2.4	18.0
200	2.367	17.0	51.8	2.566	160.1	2.3	17.9
225	2.362	16.5	50.4	2.569	160.3	2.2	17.8
250	2.356	16.5	50.5	2.573	160.6	2.0	17.7
300	2.348	16.5	50.7	2.579	160.9	1.8	17.5

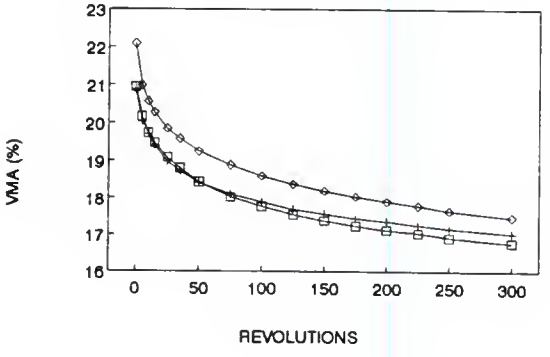
AVERAGE

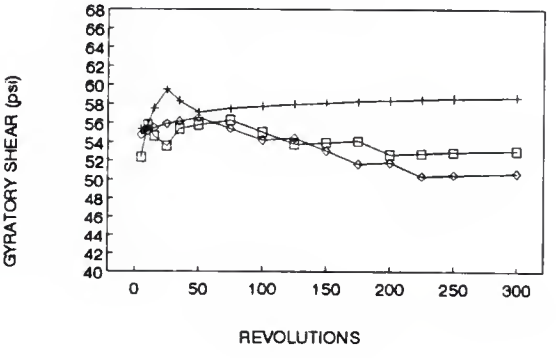
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	29.5	2.460	153.5	6.3	93.7	21.3
5	54.2	2.488	155.3	5.2	94.8	20.4
10	55.5	2.501	156.1	4.6	95.2	20.0
15	55.8	2.510	156.6	4.4	95.6	19.7
25	56.3	2.522	157.4	3.9	96.1	19.3
35	56.6	2.531	157.9	3.6	96.4	19.0
50	56.5	2.541	158.6	3.2	96.8	18.7
75	56.4	2.552	159.3	2.8	97.2	18.5
100	55.6	2.560	159.8	2.5	97.5	18.1
125	55.4	2.567	160.2	2.2	97.8	17.9
150	55.0	2.572	160.5	2.1	97.9	17.7
175	54.7	2.576	160.8	1.9	98.1	17.6
200	54.3	2.580	161.0	1.8	98.2	17.5
225	53.9	2.583	161.2	1.6	98.4	17.4
250	54.0	2.586	161.4	1.5	98.5	17.3
300	54.2	2.591	161.7	1.3	98.7	17.1

MIX ID: MARYLAND SMV









MIX ID: TEXAS SMA

GTM COMPACTION

RICE: 2.456
BSG(Agg) 2.678
BINDER % 6.4

SAMPLE STAC 64.3

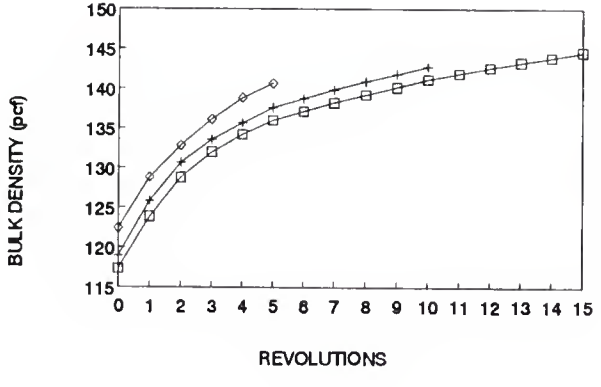
REV	HT	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.165	10.5	23.9	1.881	117.4	23.5	34.2
1	3.000			1.985	123.9	19.2	30.6
2	2.885			2.064	128.8	16.0	27.9
3	2.815			2.115	132.0	13.9	26.1
4	2.768			2.151	134.2	12.5	24.8
5	2.732	18.5	48.9	2.180	136.0	11.3	23.8
6	2.710			2.197	137.1	10.6	23.2
7	2.688			2.215	138.2	9.9	22.6
8	2.669			2.231	139.2	9.2	22.0
9	2.651			2.246	140.2	8.6	21.5
10	2.632	17.0	46.6	2.262	141.2	8.0	20.9
11	2.619			2.274	141.9	7.5	20.5
12	2.605			2.286	142.6	7.0	20.1
13	2.593			2.296	143.3	6.6	19.7
14	2.582			2.306	143.9	6.2	19.4
15	2.570	17.0	47.7	2.317	144.6	5.7	19.0

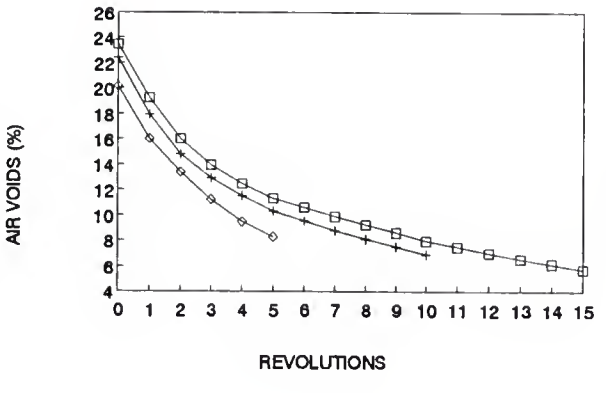
SAMPLE 5TAC 64.2

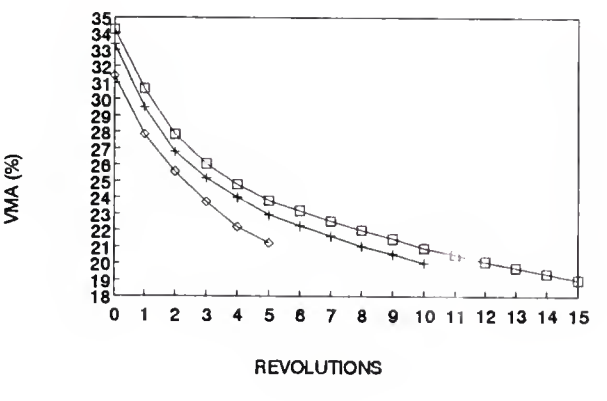
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.152	9.5	21.7	1.907	119.0	22.4	33.4
1	2.980			2.017	125.9	17.9	29.5
2	2.870			2.094	130.7	14.8	26.8
3	2.806			2.141	133.6	12.9	25.2
4	2.764			2.175	135.7	11.5	24.0
5	2.728	18.0	47.6	2.205	137.6	10.3	22.9
6	2.703			2.224	138.8	9.5	22.3
7	2.681			2.242	139.9	8.8	21.6
8	2.661			2.259	140.9	8.1	21.1
9	2.644			2.273	141.9	7.5	20.5
10	2.627	17.5	46.1	2.288	142.8	6.9	20.0

SAMPLE STAC 64.1

REV	HT	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.125	10	23.1	1.962	122.4	20.2	31.4
1	2.970			2.064	128.8	16.0	27.9
2	2.880			2.129	132.8	13.4	25.6
3	2.810			2.182	136.1	11.2	23.7
4	2.755			2.225	136.9	9.5	22.2
5	2.720	18	47.6	2.254	140.6	8.3	21.2







MIX ID. TEXAS SMA

GTM COMPACTION

RICE: 2.436
BSG(Agg) 2.676
BINDER % 6.4

SAMPLE STAC 64.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.154	0	20.6	1.893	116.1	23.0	33.6
1	2.980			2.004	123.0	16.5	30.0
2	2.890			2.066	126.8	15.9	27.6
3	2.820			2.117	132.1	13.6	26.0
4	2.772			2.134	134.4	12.4	24.7
5	2.731	16.5	43.6	2.166	136.4	11.1	23.6
6	2.705			2.207	137.7	10.2	22.6
7	2.681			2.227	139.0	9.4	22.2
8	2.660			2.245	140.1	8.7	21.5
9	2.641			2.261	141.1	8.0	21.0
10	2.620	17	46.8	2.276	142.2	7.3	20.3

SAMPLE STAC 64.5

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.156	0	20.6	1.902	118.7	22.6	33.5
1	2.950			2.036	127.0	17.2	28.6
2	2.845			2.111	131.7	14.1	26.2
3	2.765			2.156	134.6	12.3	24.6
4	2.743			2.169	136.6	10.6	23.5
5	2.706	19	50.6	2.216	136.4	9.6	22.5
6	2.690			2.232	136.3	9.2	22.0
7	2.674			2.246	140.1	8.6	21.5
8	2.656			2.259	141.0	8.1	21.0
9	2.642			2.273	141.8	7.5	20.6
10	2.627	16	49.4	2.286	142.6	7.0	20.1

SAMPLE STAC 64.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.167	0	20.5	1.917	119.6	22.0	33.0
1				ERR	ERR	ERR	ERR
2				ERR	ERR	ERR	ERR
3	2.823			2.150	134.2	12.5	24.6
4	2.790			2.176	135.6	11.5	24.0
5	2.755	17.5	45.6	2.203	137.5	10.4	23.0
6	2.730			2.223	138.7	9.5	22.3
7	2.706			2.242	139.9	8.6	21.7
8	2.687			2.256	141.0	8.1	21.0
9	2.670			2.273	141.9	7.5	20.3
10	2.653	16	49.0	2.288	142.8	6.9	20.0

SAMPLE STAC 64.7

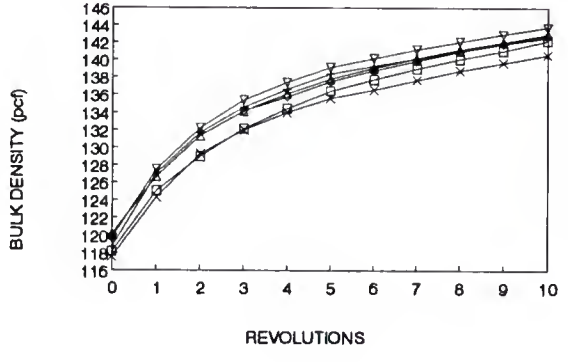
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.137	10	23.6	1.923	120.1	21.7	32.7
1	2.975			2.030	126.7	17.4	29.1
2	2.870			2.104	131.3	14.4	26.5
3	2.810			2.149	134.1	12.6	24.9
4	2.766			2.182	136.1	11.2	23.7
5	2.735	16	47.5	2.206	137.8	10.2	22.8
6	2.710			2.226	139.1	9.3	22.1
7	2.688			2.247	140.2	8.6	21.5
8	2.669			2.263	141.2	7.9	20.9
9	2.653			2.276	142.0	7.4	20.4
10	2.636	16	46.3	2.291	143.0	6.8	19.9

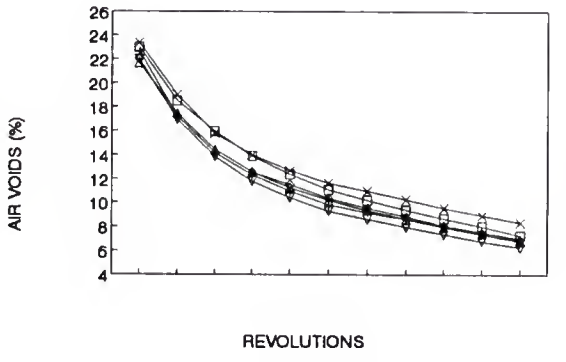
SAMPLE STAC 64.8

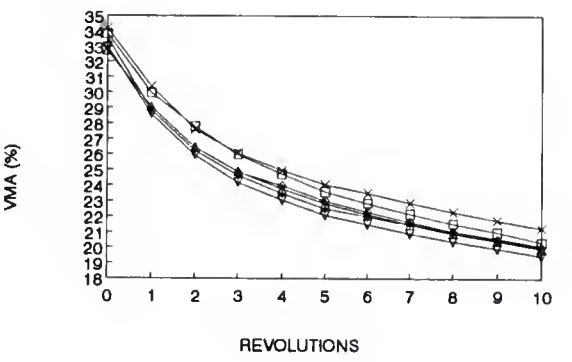
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.172	9	26.5	1.884	117.5	23.4	34.2
1	3.000			1.992	124.3	19.6	30.4
2	2.885			2.071	129.2	15.7	27.6
3	2.825			2.115	132.0	14.0	26.1
4	2.783			2.147	134.0	12.7	25.0
5	2.750	16	47.2	2.173	133.6	11.6	24.1
6	2.730			2.189	136.6	11.0	23.5
7	2.708			2.206	137.7	10.2	22.9
8	2.687			2.224	138.6	9.5	22.3
9	2.669			2.239	139.7	8.9	21.8
10	2.652	16	43.5	2.253	140.5	8.3	21.3

SAMPLE STAC 64.9

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.169	0	20.5	1.916	119.7	22.0	33.0
1	2.975			2.043	127.5	16.9	28.6
2	2.869			2.116	132.2	13.8	26.0
3	2.802			2.159	135.4	11.8	24.2
4	2.760			2.202	137.4	10.4	23.0
5	2.726	16.5	49.6	2.230	139.1	9.3	22.1
6	2.706			2.246	140.2	8.6	21.5
7	2.686			2.263	141.2	7.9	20.9
8	2.669			2.277	142.1	7.4	20.4
9	2.653			2.291	143.0	6.8	19.9
10	2.638	16	49.2	2.304	143.8	6.3	19.5







MIX ID: TEXAS SMA

GTM DENSIFICATION

RICE:	2.456	BSGcomp	2.284
BSG(Agg)	2.670	HTcomp	2.638
BINDER %	6.4	REVcomp	10

SAMPLE STAC 64.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.636	9.5	26.0	2.286	142.6	7.0	20.1
5	2.564	16.5	46.4	2.317	144.6	5.7	19.0
10	2.534	16.5	47.0	2.330	145.4	5.2	18.6
15	2.513	16.5	47.4	2.339	146.0	4.8	18.2
25	2.493	16.5	48.0	2.352	146.8	4.3	17.8
35	2.480	16.5	48.4	2.362	147.4	3.9	17.4
50	2.466	16.5	48.8	2.372	148.0	3.5	17.1
75	2.414	16.0	47.6	2.382	148.6	3.1	16.7
100	2.397	16.5	49.7	2.389	149.1	2.8	16.5
125	2.385	16.5	49.9	2.398	149.4	2.6	16.3
150	2.376	16.5	50.1	2.399	149.7	2.4	16.2
175	2.369	17.0	51.6	2.402	149.9	2.3	16.1
200	2.363	17.0	51.9	2.404	150.0	2.2	16.0
225	2.357	17.0	52.0	2.407	150.2	2.1	15.9
250	2.352	17.5	53.7	2.409	150.3	2.0	15.8
300	2.345	17.5	53.9	2.412	150.5	1.9	15.7

SAMPLE STAC 64.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.593	12.0	33.4	2.324	145.0	5.5	18.6
5	2.534	17.0	46.4	2.345	146.5	4.6	18.1
10	2.508	17.0	49.0	2.355	147.0	4.2	17.7
15	2.484	17.0	49.4	2.362	147.4	3.9	17.4
25	2.456	17.0	49.9	2.372	148.0	3.5	17.1
35	2.435	16.5	48.9	2.380	148.5	3.2	16.8
50	2.413	17.0	50.8	2.388	149.0	2.9	16.5
75	2.369	16.5	49.8	2.398	149.5	2.5	16.2
100	2.374	16.5	50.2	2.402	149.9	2.3	16.1
125	2.364	16.5	50.4	2.405	150.1	2.1	15.9
150	2.357	17.0	52.0	2.406	150.2	2.0	15.8
175	2.351	17.0	52.2	2.410	150.4	2.0	15.8
200	2.345	17.0	52.3	2.412	150.5	1.9	15.7
225	2.340	17.0	52.4	2.414	150.6	1.8	15.6
250	2.336	17.0	52.5	2.415	150.7	1.7	15.6
300	2.328	16.0	49.6	2.418	150.9	1.6	15.5

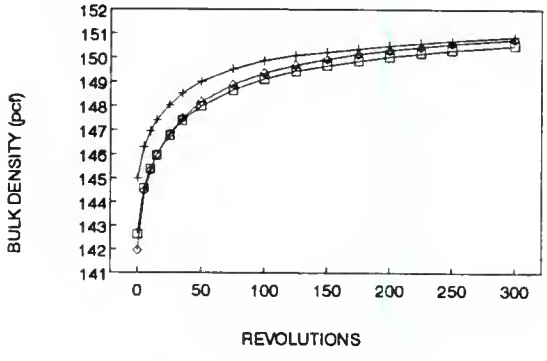
SAMPLE STAC 64.12

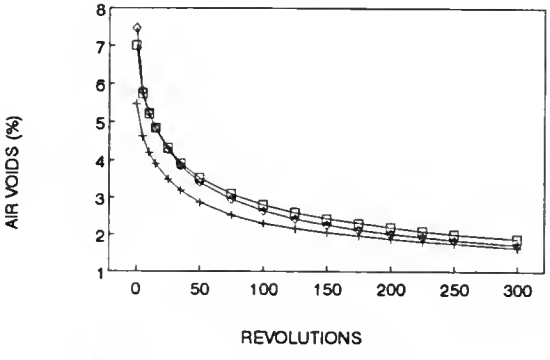
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.649	10.0	27.2	2.275	141.9	7.5	20.5
5	2.555	17.5	49.4	2.313	144.5	5.8	19.1
10	2.523	17.0	49.6	2.329	145.5	5.2	18.6
15	2.499	16.5	47.6	2.339	146.0	4.8	18.2
25	2.467	16.0	46.6	2.353	146.8	4.3	17.8
35	2.443	16.5	48.7	2.364	147.5	3.8	17.4
50	2.418	16.0	47.7	2.374	148.2	3.4	17.0
75	2.392	16.0	48.3	2.388	148.9	2.9	16.6
100	2.374	16.5	50.2	2.394	149.4	2.6	16.3
125	2.362	16.0	48.9	2.399	149.7	2.4	16.2
150	2.353	16.0	49.1	2.403	149.9	2.3	16.0
175	2.345	16.0	49.2	2.406	150.1	2.1	15.9
200	2.339	16.5	50.9	2.409	150.3	2.0	15.8
225	2.334	16.5	51.0	2.411	150.4	1.9	15.7
250	2.329	17.0	52.7	2.413	150.6	1.8	15.7
300	2.322	17.0	52.8	2.416	150.8	1.7	15.6

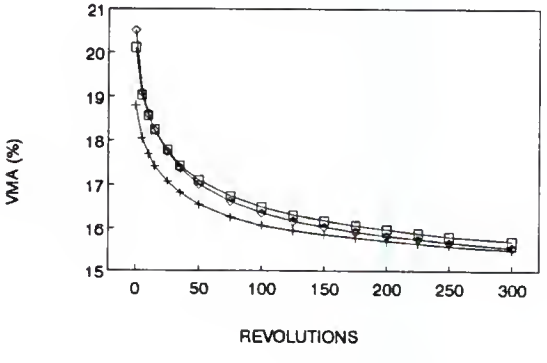
AVERAGE

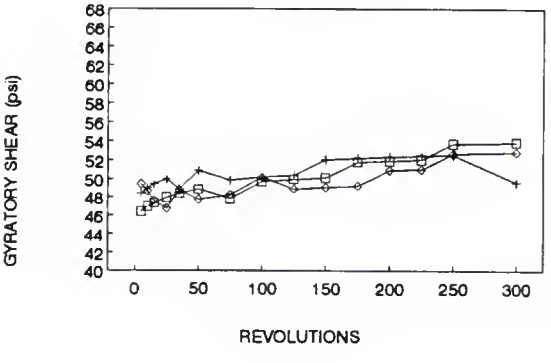
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	28.9	2.295	143.2	6.6	93.4	19.6
5	48.1	2.326	145.1	5.4	94.6	18.7
10	48.2	2.336	145.9	4.9	95.1	18.3
15	48.1	2.347	146.5	4.5	95.5	18.0
25	48.2	2.359	147.2	4.0	96.0	17.5
35	49.7	2.369	147.8	3.6	96.4	17.2
50	49.1	2.378	148.4	3.3	96.7	16.9
75	48.6	2.388	149.0	2.9	97.2	16.5
100	50.0	2.395	149.4	2.6	97.4	16.3
125	49.7	2.400	149.7	2.4	97.6	16.1
150	50.4	2.403	149.9	2.2	97.8	16.0
175	51.1	2.406	150.1	2.1	97.9	15.9
200	51.7	2.408	150.3	2.0	98.0	15.8
225	51.8	2.410	150.4	1.9	98.1	15.8
250	53.0	2.412	150.5	1.9	98.1	15.7
300	52.1	2.415	150.7	1.7	98.3	15.6

MIX ID: BLANK









MIX ID: VIRGINIA, ARBOCEL (VA1)

GTM COMPACTION

RICE: 2.47
BSG(Agg) 2.71
BINDER % 6.2

SAMPLE SVAr62.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.174	9.0	20.5	1.878	117.1	24.0	35.1
1	3.027			1.967	122.7	20.4	31.9
2	2.918			2.041	127.3	17.4	29.4
3	2.840			2.090	130.4	15.4	27.7
4	2.786			2.127	132.7	13.9	26.4
5	2.764	19.0	49.6	2.154	134.4	12.8	25.4
6	2.740			2.173	135.6	12.0	24.8
7	2.717			2.192	136.8	11.3	24.1
8	2.697			2.208	137.8	10.8	23.6
9	2.678			2.223	138.7	10.0	23.0
10	2.662	19.0	51.5	2.237	139.6	9.4	22.6
11	2.648			2.249	140.3	9.0	22.2
12	2.635			2.260	141.0	8.5	21.8
13	2.623			2.270	141.7	8.1	21.4
14	2.612			2.280	142.3	7.7	21.1
15	2.600	18.8	52.2	2.290	142.9	7.3	20.7
16	2.590			2.299	143.5	6.9	20.4
17	2.581			2.307	144.0	6.6	20.1
18	2.572	18.8	52.2	2.315	144.5	6.3	19.9
19	2.564			2.322	144.9	6.0	19.6
20	2.556			2.328	145.3	5.8	19.4
21	2.548			2.337	145.8	5.4	19.1
22	2.54			2.344	146.3	5.1	18.9
23	2.534			2.350	146.6	4.9	18.7
24	2.528			2.355	147.0	4.6	18.5
25	2.522	19.0	54.4	2.361	147.3	4.4	18.3

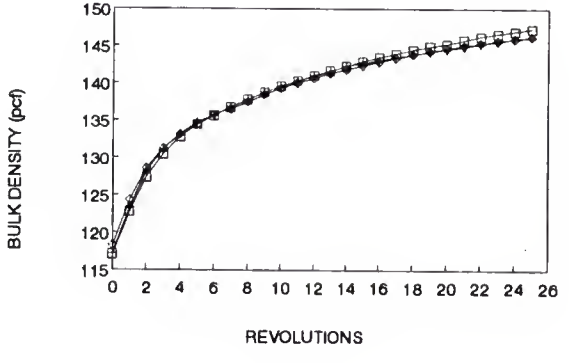
SAMPLE SVAr62.5

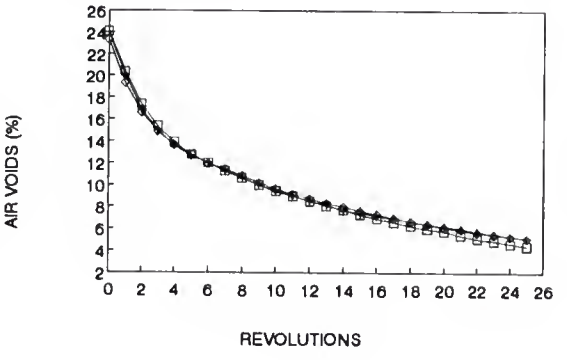
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.173	9.0	20.5	1.878	117.2	24.0	35.0
1	3.018			1.974	123.2	20.1	31.7
2	2.900			2.055	128.2	16.8	28.9
3	2.836			2.100	131.0	15.0	27.3
4	2.782			2.134	133.2	13.6	26.1
5	2.761	19.5	51.6	2.156	134.7	12.8	25.3
6	2.740			2.175	135.7	12.0	24.7
7	2.718			2.192	136.8	11.2	24.1
8	2.698			2.208	137.8	10.6	23.6
9	2.680			2.225	138.7	10.0	23.0
10	2.663	19.7	53.4	2.237	139.6	9.4	22.6
11	2.650			2.248	140.3	9.0	22.2
12	2.637			2.260	141.0	8.5	21.8
13	2.627			2.268	141.5	8.2	21.5
14	2.612			2.281	142.3	7.6	21.0
15	2.606	20.3	56.2	2.286	142.7	7.4	20.9
16	2.598			2.293	143.1	7.2	20.8
17	2.592			2.299	143.4	6.9	20.4
18	2.585	20.0	55.8	2.305	143.8	6.7	20.2
19	2.578			2.311	144.2	6.4	20.0
20	2.572	19.5	54.7	2.317	144.6	6.2	19.8
21	2.566			2.322	144.9	6.0	19.6
22	2.559			2.328	145.3	5.7	19.4
23	2.553			2.334	145.6	5.5	19.2
24	2.547			2.339	146.0	5.3	19.0
25	2.542	18.8	53.4	2.344	146.3	5.1	18.9

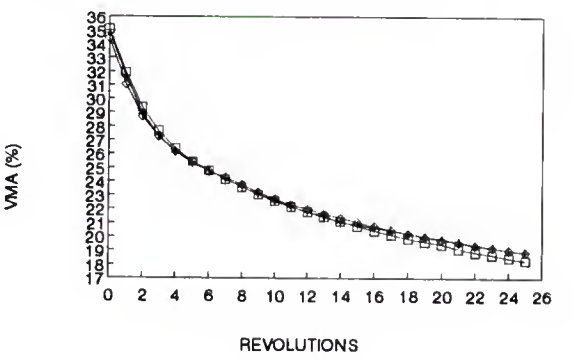
SAMPLE SVAr62.6

	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.144	9	20.7	1.895	118.3	25.3	34.4
1	2.990			1.993	124.4	19.3	31.0
2	2.882			2.060	128.6	16.6	28.7
3	2.834			2.102	131.2	14.9	27.2
4	2.793			2.133	133.1	13.6	26.2
5	2.766	19.5	50.9	2.154	134.4	12.8	25.4
6	2.739			2.175	135.7	11.9	24.7
7	2.724			2.187	136.5	11.4	24.3
8	2.705			2.203	137.5	10.8	23.8
9	2.688			2.218	138.4	10.2	23.2
10	2.669	19.5	52.7	2.232	139.3	9.6	22.7
11	2.655			2.244	140.0	9.1	22.3
12	2.644			2.254	140.6	8.8	22.0
13	2.632			2.264	141.3	8.3	21.8
14	2.622			2.272	141.8	8.0	21.5
15	2.612	19	52.5	2.281	142.3	7.6	21.0
16	2.603			2.288	142.8	7.3	20.8
17	2.593			2.296	143.4	7.0	20.5
18	2.585	19	55.0	2.305	143.8	6.7	20.2
19	2.577			2.312	144.3	6.4	20.0
20	2.570	18.8	52.8	2.318	144.7	6.1	19.8
21	2.564			2.324	145.0	5.9	19.6
22	2.557			2.330	145.4	5.7	19.3
23	2.552			2.335	145.7	5.5	19.2
24	2.547			2.339	146.0	5.3	19.0
25	2.542	19	53.9	2.344	146.3	5.1	18.9

ESTIMATED







MIX ID: VIRGINIA, ARBOCEL (VA1)

GTM COMPACTION

RICE: 2.47
BSG(Agg) 2.71
BINDER % 6.2

SAMPLE SVAr62.8

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.062	9.0	21.1	1.961	122.3	20.6	32.1
2	2.853	19.0	46.1	2.116	132.2	14.2	26.7
4	2.761	21.0	54.6	2.169	136.6	11.4	24.2
6	2.719	21.0	55.7	2.222	138.7	10.0	23.1
8	2.680	22.0	59.2	2.255	140.7	8.7	22.0
10	2.654	23.0	62.5	2.277	142.1	7.8	21.2
12	2.632	22.0	60.3	2.296	143.3	7.0	20.5
14	2.616	22.0	60.7	2.310	144.1	6.5	20.0
15	2.608	21.5	59.5	2.317	144.6	6.2	19.8

SAMPLE SVAr62.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.122	9.5	22.0	1.926	120.3	22.0	33.3
1	2.957			2.035	127.0	17.6	29.6
2	2.846			2.113	131.9	14.4	26.9
3	2.790			2.157	134.6	12.7	25.5
4	2.748			2.190	136.7	11.3	24.2
5	2.713	20.0	53.2	2.216	138.4	10.2	23.2
6	2.690			2.237	139.6	9.4	22.6
7	2.666			2.256	140.8	8.7	21.9
8	2.651			2.270	141.7	8.1	21.4
9	2.637			2.282	142.4	7.6	21.0
10	2.625	22.0	60.5	2.293	143.1	7.2	20.6
11	2.614			2.302	143.7	6.8	20.3
12	2.603	21.5	59.6	2.312	144.3	6.4	20.0

SAMPLE SVAr62.13

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.180	9.0	20.4	1.931	120.5	21.6	33.2
1	2.998			2.055	128.2	16.6	28.9
2	2.876			2.133	133.1	15.6	26.2
3	2.814			2.182	136.2	11.7	24.5
4	2.767			2.216	138.5	10.2	23.2
5	2.731	16.5	46.9	2.246	140.5	9.0	22.2
6	2.711			2.265	141.3	8.5	21.6
7	2.690			2.283	142.4	7.8	21.0
8	2.671			2.299	143.4	6.9	20.4
9	2.654			2.313	144.4	6.3	19.9
10	2.639	19.0	52.0	2.327	145.2	5.6	19.5
11	2.626			2.338	145.9	5.5	19.1
12	2.615	19.0	52.4	2.346	146.5	4.9	18.7

SAMPLE SVAr62.11

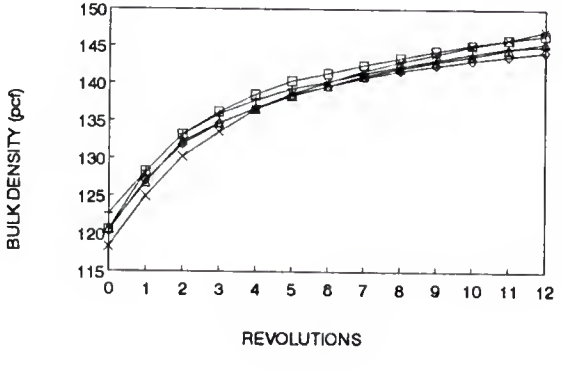
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.158	10.0	22.6	1.932	120.6	21.6	33.1
1	3.005			2.031	126.7	17.6	29.7
2	2.880			2.119	132.2	14.2	26.7
3	2.820			2.156	134.7	12.6	25.3
4	2.788			2.186	136.6	11.4	24.2
5	2.753	19.0	49.6	2.217	138.3	10.3	23.3
6	2.727			2.236	139.6	9.4	22.5
7	2.701			2.259	141.0	8.5	21.8
8	2.682			2.275	142.0	7.9	21.2
9	2.665			2.290	142.9	7.3	20.7
10	2.650	19.0	51.7	2.303	143.7	6.8	20.3
11	2.633			2.316	144.6	6.2	19.8
12	2.616	19.5	53.7	2.331	145.5	5.6	19.5

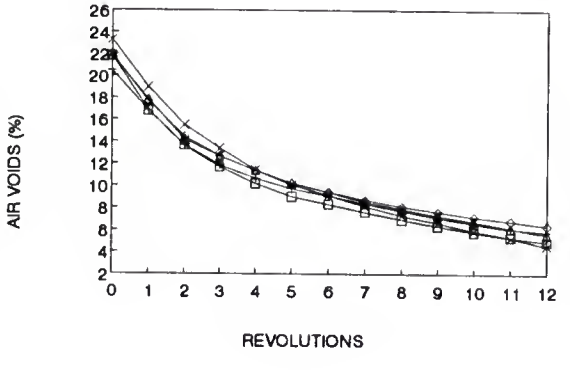
SAMPLE SVAr62.9

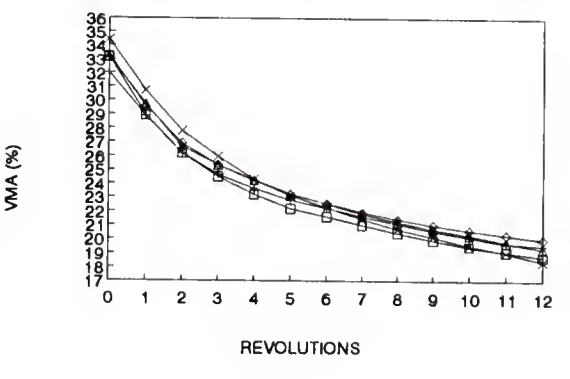
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.090	9.5	22.2	1.965	122.6	20.4	32.9
1	2.955			2.055	128.2	16.6	28.9
2	2.847			2.133	133.1	13.6	26.2
3	2.789			2.177	135.9	11.8	24.6
4	2.752			2.207	137.7	10.7	23.6
5	2.722	20.0	53.0	2.231	139.2	9.7	22.8
6	2.703			2.247	140.2	9.0	22.2
7	2.682			2.264	141.3	8.5	21.6
8	2.664			2.280	142.2	7.7	21.1
9	2.647			2.294	143.2	7.1	20.6
10	2.632	20.0	54.6	2.307	144.0	6.6	20.1
11	2.618			2.320	144.7	6.1	19.7
12	2.612	20.0	55.3	2.325	145.1	5.9	19.5

SAMPLE SVAr62,12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.210	9.5	21.4	1.895	118.3	23.3	34.4
1	3.038			2.002	125.0	18.9	30.7
2	2.915			2.087	130.2	15.5	27.8
3	2.843			2.140	133.5	13.4	25.9
4	2.781			2.187	136.5	11.4	24.3
5	2.739	15.5	40.6	2.221	138.6	10.1	23.1
6	2.709			2.246	140.1	9.1	22.3
7	2.680			2.270	141.6	8.1	21.4
8	2.656			2.290	142.9	7.3	20.7
9	2.637			2.307	144.0	6.6	20.2
10	2.617	15.5	42.7	2.325	145.1	5.9	19.5
11	2.601			2.339	145.9	5.3	19.0
12	2.581	16.0	44.7	2.357	147.1	4.6	18.4







MIX ID: WHITEROCKSMA (FL1)

GTM COMPACTION

RICE. 2.351
BSG(Agg) 2.447
BINDER % 6.0

SAMPLE SWAR 60.1

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.211	9	20.2	1.793	111.9	23.7	31.1
1	3.075			1.873	116.9	20.3	26.1
2	2.962			1.944	121.3	17.3	25.3
3	2.878			2.001	124.9	14.9	25.1
4	2.825			2.036	127.2	13.3	21.7
5	2.785	16.5	47.9	2.066	129.0	12.0	20.6
6	2.76			2.086	130.2	11.3	19.6
7	2.734			2.106	131.4	10.4	19.1
8	2.711			2.124	132.5	9.6	18.4
9	2.690			2.141	133.6	8.9	17.8
10	2.674	19	51.3	2.154	134.4	8.4	17.3
11	2.658			2.167	135.2	7.8	16.8
12	2.645			2.177	135.9	7.4	16.4
13	2.633			2.187	136.5	7.0	16.0
14	2.622			2.196	137.0	6.6	15.6
15	2.614	19.3	53.6	2.203	137.3	6.3	15.4

SAMPLE SWAR 60.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.219	9.5	21.3	1.784	111.3	24.1	31.5
1	3.060			1.877	117.1	20.2	27.9
2	2.939			1.954	122.0	16.9	24.9
3	2.852			2.007	125.2	14.6	22.9
4	2.812			2.043	127.5	13.1	21.5
5	2.775	19	49.4	2.070	129.2	12.0	20.5
6	2.753			2.086	130.2	11.3	19.9
7	2.726			2.109	131.4	10.4	19.1
8	2.707			2.122	132.4	9.7	18.5
9	2.686			2.137	133.3	9.1	17.9
10	2.669	19	51.4	2.152	134.3	8.5	17.3
11	2.656			2.163	134.9	8.0	16.9
12	2.644			2.172	135.6	7.6	16.5
13	2.632			2.182	136.2	7.2	16.2
14	2.622			2.191	136.7	6.8	15.8
15	2.612	19.5	53.9	2.199	137.2	6.5	15.5

SAMPLE SWAR 60.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.203	9.5	21.4	1.784	111.3	24.1	31.5
1	3.056			1.870	116.7	20.4	28.2
2	2.950			1.950	121.7	17.1	25.1
3	2.862			1.996	124.6	15.1	23.3
4	2.815			2.030	126.7	13.7	22.0
5	2.775	20	52.0	2.059	128.3	12.4	20.9
6	2.755			2.074	129.4	11.6	20.3
7	2.732			2.091	130.5	11.0	19.7
8	2.711			2.106	131.5	10.4	19.0
9	2.692			2.123	132.4	9.7	18.5
10	2.676	20.5	55.3	2.135	133.2	9.2	18.0
11	2.661			2.147	134.0	8.7	17.5
12	2.649			2.157	134.6	8.3	17.1
13	2.636			2.166	135.3	7.8	16.7
14	2.624			2.176	135.9	7.4	16.4
15	2.615	20.5	56.6	2.185	136.3	7.1	16.1

SAMPLE SWAR 60.4

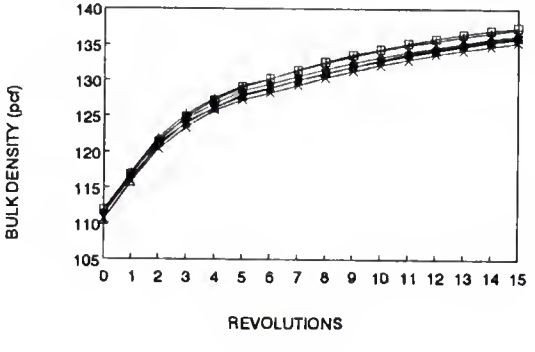
REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.254	9.5	21.1	1.769	110.4	24.7	32.0
1	3.105			1.854	115.7	21.1	28.6
2	2.985			1.942	121.2	17.4	25.4
3	2.898			1.987	124.0	15.3	23.7
4	2.850			2.020	126.1	14.1	22.4
5	2.812	19	48.6	2.048	127.8	12.9	21.3
6	2.789			2.064	128.8	12.2	20.7
7	2.764			2.083	130.0	11.4	20.0
8	2.742			2.100	131.0	10.7	19.3
9	2.723			2.115	131.9	10.1	18.8
10	2.705	19	50.7	2.129	132.8	9.5	18.2
11	2.687			2.143	133.7	8.9	17.7
12	2.675			2.152	134.3	8.4	17.3
13	2.662			2.163	135.0	8.0	16.9
14	2.650			2.173	135.6	7.6	16.5
15	2.640	19	51.9	2.181	136.1	7.2	16.2

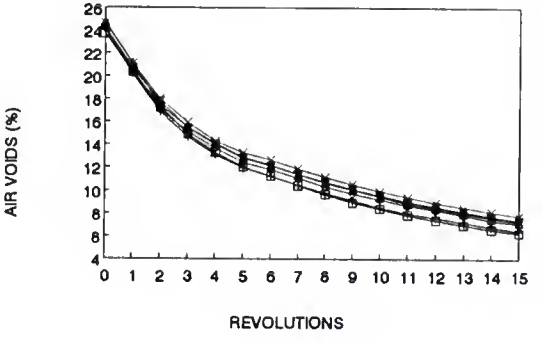
SAMPLE SWAR 60.5

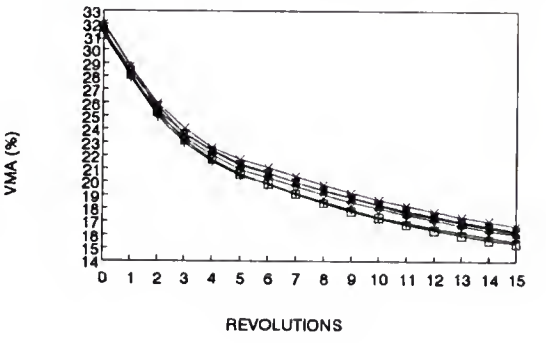
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.241	12	20.7	1.772	110.6	24.6	31.9
1	3.095			1.858	115.8	21.1	28.7
2	2.978			1.929	120.3	18.0	25.9
3	2.905			1.977	123.4	15.9	24.1
4	2.850			2.013	125.6	14.3	22.8
5	2.817	19.5	50.0	2.039	127.2	13.3	21.7
6	2.796			2.054	128.2	12.6	21.1
7	2.772			2.072	129.3	11.9	20.4
8	2.750			2.089	130.3	11.2	19.8
9	2.730			2.104	131.3	10.5	19.2
10	2.712	19.5	51.9	2.118	132.2	9.9	18.6
11	2.697			2.130	132.9	9.4	18.2
12	2.682			2.142	133.8	8.9	17.7
13	2.670			2.151	134.2	8.5	17.4
14	2.659			2.160	134.8	8.1	17.0
15	2.648	19	51.6	2.169	135.3	7.7	16.7

SAMPLE SWAR 60.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.221	10.5	23.5	1.783	111.3	24.2	31.5
1	3.080			1.865	116.4	20.7	28.4
2	2.970			1.954	120.7	17.7	25.7
3	2.888			1.989	124.1	15.4	23.6
4	2.841			2.022	126.1	14.0	22.3
5	2.802	20	51.5	2.050	127.9	12.8	21.3
6	2.780			2.066	128.9	12.1	20.8
7	2.757			2.083	130.0	11.4	20.0
8	2.737			2.098	130.9	10.7	19.4
9	2.716			2.113	131.9	10.1	18.8
10	2.701	19.3	52.1	2.126	132.7	9.6	18.3
11	2.686			2.138	133.5	9.0	17.8
12	2.672			2.149	134.1	8.6	17.4
13	2.659			2.160	134.8	8.1	17.0
14	2.647			2.170	135.4	7.7	16.6
15	2.637	20	54.7	2.178	135.9	7.4	16.3







MIX ID: WHITEROCKSMA (FL1) GTM DENSIFICATION

RICE:	2.351	BSGcomp	2.165
BSG(Agg)	2.447	HTcomp	2.628
BINDER %	6.0	REVcomp	15

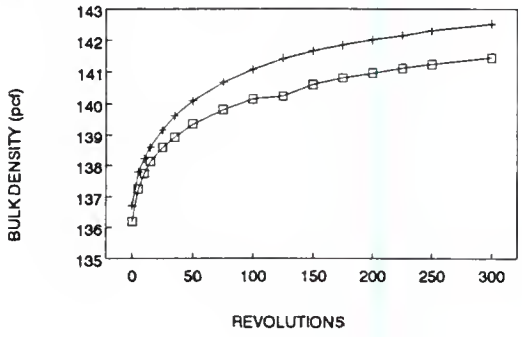
SAMPLE SWAR 60.5

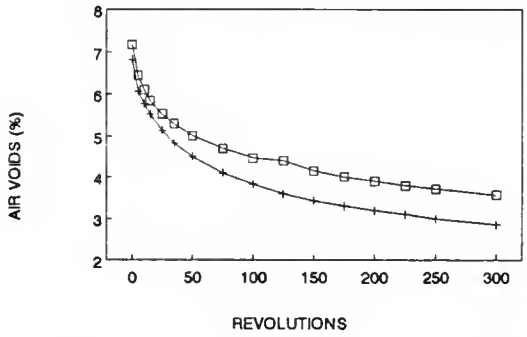
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.631	11.0	30.2	2.183	136.2	7.2	16.2
5	2.596	21.5	59.6	2.200	137.3	6.4	15.5
10	2.580	22.0	61.5	2.207	137.7	6.1	15.2
15	2.567	22.0	61.8	2.214	138.1	5.8	15.0
25	2.552	22.0	62.2	2.221	138.6	5.5	14.7
36	2.541	22.0	62.5	2.226	138.9	5.5	14.5
50	2.527	22.0	62.6	2.233	139.4	5.0	14.2
75	2.512	22.0	63.2	2.241	139.8	4.7	15.9
100	2.501	22.0	63.5	2.246	140.2	4.5	15.7
125	2.498	22.0	63.8	2.247	140.2	4.4	15.7
150	2.486	22.0	63.9	2.253	140.6	4.2	15.4
175	2.479	22.0	64.0	2.257	140.8	4.0	15.3
200	2.474	22.9	65.6	2.259	141.0	5.9	13.2
225	2.469	23.0	67.2	2.262	141.1	5.8	15.1
250	2.465	23.0	67.3	2.264	141.2	5.7	15.0
300	2.456	23.0	67.5	2.267	141.5	5.6	12.9

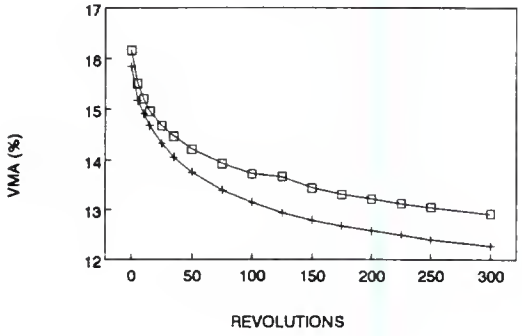
SAMPLE SWAR 60.6

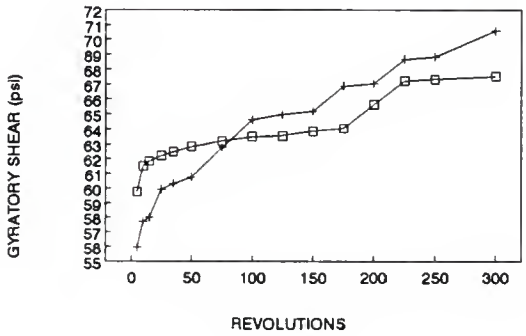
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.621	10.5	28.9	2.191	136.7	6.8	15.8
5	2.580	20.0	55.9	2.208	137.8	6.1	15.2
10	2.564	20.5	57.7	2.215	138.2	5.8	14.9
15	2.550	20.5	58.0	2.221	138.6	5.5	14.7
25	2.529	21.0	59.9	2.230	139.2	5.1	14.5
36	2.512	21.0	60.5	2.237	139.6	4.8	14.1
50	2.494	21.0	60.8	2.245	140.1	4.5	15.8
75	2.472	21.5	62.8	2.256	140.7	4.1	15.4
100	2.457	22.0	64.6	2.261	141.1	3.8	15.1
125	2.444	22.0	65.0	2.266	141.4	3.6	12.9
150	2.435	22.0	65.2	2.270	141.7	3.4	12.8
175	2.428	22.5	66.9	2.273	141.9	3.5	12.7
200	2.422	22.5	67.0	2.276	142.0	3.2	12.6
225	2.417	23.0	68.7	2.278	142.1	3.1	12.5
250	2.411	23.0	68.8	2.281	142.5	3.0	12.4
300	2.403	23.5	70.6	2.284	142.5	2.8	12.5

MIX ID: SWAR60









MIX ID: FLA CRUSHED STONE (FL2)

GTM COMPACTION

RICE: 2.311
BSG(Agg) 2.397
BINDER % 5.3

SAMPLE SFAR 53.1

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.152	10	22.9	1.765	110.1	25.6	30.5
1	3.030			1.836	114.6	20.5	27.5
2	2.936			1.896	118.3	18.0	25.1
3	2.872			1.937	120.9	16.2	23.5
4	2.829			1.967	122.7	14.9	22.3
5	2.792	19.5	50.4	1.993	124.3	13.8	21.3
6	2.769			2.009	125.4	13.1	20.6
7	2.747			2.025	126.4	12.4	20.0
8	2.724			2.042	127.5	11.6	19.3
9	2.703			2.056	128.4	10.9	18.7
10	2.683	19	51.1	2.074	129.4	10.3	18.1
11	2.669			2.065	130.1	9.8	17.6
12	2.655			2.096	130.8	9.3	17.2
13	2.643			2.105	131.4	8.9	16.8
14	2.630			2.115	132.0	8.5	16.4
15	2.617	19	52.4	2.128	132.7	8.0	16.0

SAMPLE SFAR 53.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.271	9	19.9	1.742	108.7	24.6	31.2
1	3.115			1.830	114.2	20.8	27.7
2	3.008			1.895	118.2	18.0	25.1
3	2.936			1.940	121.0	16.1	23.4
4	2.866			1.975	123.2	14.5	22.0
5	2.850	18	45.6	2.000	124.8	13.5	21.0
6	2.825			2.017	125.9	12.7	20.3
7	2.800			2.035	127.0	11.9	19.6
8	2.779			2.051	128.0	11.3	19.0
9	2.759			2.066	128.9	10.6	18.4
10	2.742	18.5	48.7	2.079	129.7	10.1	17.9
11	2.728			2.089	130.4	9.6	17.5
12	2.713			2.101	131.1	9.1	17.0
13	2.701			2.110	131.7	8.7	16.6
14	2.689			2.119	132.3	8.5	16.3
15	2.677	18.5	49.9	2.129	132.9	7.9	15.9

SAMPLE SFAR 53.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.233	9	20.1	1.764	110.1	23.7	30.5
1	3.080			1.852	115.5	19.9	26.8
2	2.970			1.920	119.8	18.9	24.1
3	2.900			1.967	122.7	14.9	22.5
4	2.850			2.001	124.9	13.4	20.9
5	2.808	18	48.3	2.031	126.7	12.1	19.8
6	2.781			2.031	126.8	11.5	19.6
7	2.757			2.069	129.1	10.5	19.3
8	2.735			2.066	130.1	9.8	17.8
9	2.715			2.101	131.1	9.1	17.0
10	2.696	18	48.2	2.118	132.0	8.5	16.4
11	2.682			2.127	132.7	8.0	16.0
12	2.669			2.137	133.5	7.5	15.6
13	2.657			2.147	133.9	7.1	15.2
14	2.647			2.155	134.5	6.6	14.9
15	2.636	18	49.2	2.162	134.9	6.4	14.6

SAMPLE SFAR 53.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.259	9	19.9	1.746	108.9	24.5	31.0
1	3.105			1.832	114.3	20.7	27.6
2	3.000			1.897	118.3	17.9	25.1
3	2.935			1.939	121.0	16.1	23.4
4	2.882			1.974	123.2	14.8	22.0
5	2.840	18	45.7	2.003	125.0	13.5	20.8
6	2.813			2.023	126.2	12.5	20.1
7	2.787			2.042	127.4	11.7	19.3
8	2.765			2.056	128.4	11.0	18.7
9	2.745			2.073	129.5	10.3	18.1
10	2.726	18	47.6	2.087	130.2	9.7	17.5
11	2.712			2.096	130.9	9.2	17.1
12	2.697			2.116	131.6	8.7	16.7
13	2.684			2.120	132.3	8.3	16.2
14	2.672			2.129	132.9	7.9	15.9
15	2.660	17.5	47.5	2.139	133.5	7.4	15.5

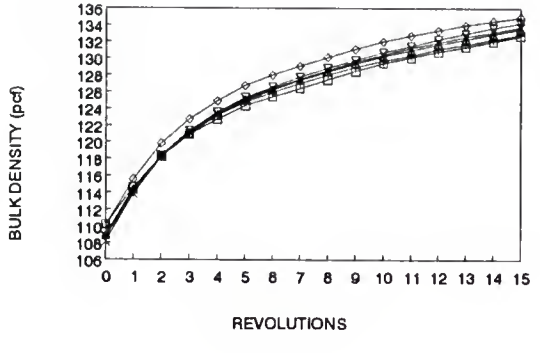
SAMPLE SFAR 53.5

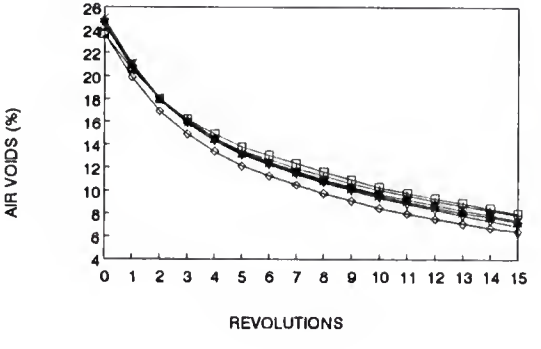
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.241	9	20.0	1.734	108.2	25.0	31.5
1	3.081			1.824	113.8	21.1	27.9
2	2.967			1.894	118.2	18.1	25.2
3	2.890			1.944	121.3	15.9	23.2
4	2.844			1.976	123.3	14.5	21.9
5	2.801	18	46.4	2.008	125.2	13.2	20.7
6	2.775			2.025	126.4	12.4	20.0
7	2.750			2.043	127.5	11.6	19.3
8	2.727			2.060	128.6	10.8	18.6
9	2.707			2.076	129.5	10.2	18.0
10	2.686	18	48.3	2.090	130.4	9.5	17.4
11	2.672			2.103	131.2	9.0	16.9
12	2.656			2.114	131.9	8.5	16.5
13	2.645			2.124	132.6	8.1	16.1
14	2.634			2.133	133.1	7.7	15.7
15	2.622	18	49.5	2.143	133.7	7.3	15.3

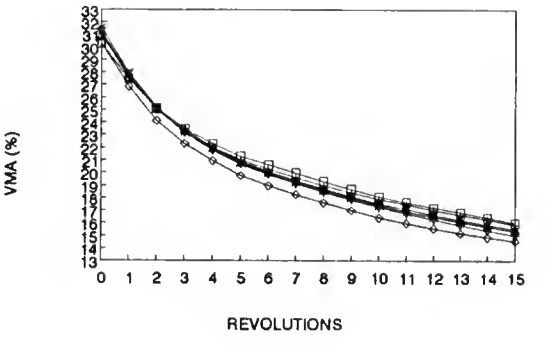
SAMPLE SFAR 53.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.271	9	19.9	1.742	108.7	24.6	31.2
1	3.120			1.826	114.0	21.0	27.6
2	3.003			1.897	118.4	17.9	25.0
3	2.930			1.945	121.5	15.8	23.2
4	2.877			1.981	123.6	14.3	21.8
5	2.837	18	45.8	2.008	125.3	13.1	20.7
6	2.809			2.026	126.6	12.2	19.9
7	2.783			2.047	127.8	11.4	19.1
8	2.760			2.064	128.8	10.7	18.4
9	2.740			2.080	129.8	10.0	17.8
10	2.720	18	47.6	2.095	130.7	9.4	17.2
11	2.704			2.107	131.5	8.8	16.7
12	2.689			2.119	132.2	8.3	16.3
13	2.674			2.131	133.0	7.8	15.8
14	2.661			2.141	133.6	7.5	15.4
15	2.649	18	49.0	2.151	134.2	6.9	15.0

MIX ID: SFAR 53







MIX ID: FLA CRUSHED STONE (FL2)

GTM DENSIFICATION

RICE:	2.311	BSGcomp	2.142
BSG(Agg)	2.397	HTcomp	2.644
BINDER %	5.3	REVcomp	15

SAMPLE SFAR 53.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.635	11.0	30.1	2.149	134.1	7.0	15.1
5	2.586	16.5	46.0	2.171	135.5	6.1	14.2
10	2.563	17.0	47.9	2.182	136.2	5.6	13.8
15	2.544	18.0	51.1	2.191	136.7	5.2	13.4
25	2.519	18.0	51.6	2.203	137.4	4.7	13.0
35	2.500	18.0	52.0	2.211	138.0	4.3	12.6
50	2.478	19.0	56.3	2.222	138.6	3.9	12.2
75	2.452	19.5	57.4	2.234	139.4	3.4	11.8
100	2.436	19.5	57.8	2.241	139.8	3.0	11.5
125	2.421	20.0	59.6	2.248	140.3	2.7	11.2
150	2.411	20.0	59.9	2.252	140.5	2.5	11.0
175	2.401	20.0	60.1	2.257	140.8	2.3	10.8
200	2.392	20.0	60.3	2.261	141.1	2.2	10.7
225	2.381	20.0	60.6	2.268	141.4	1.9	10.5
250	2.376	20.0	60.7	2.268	141.6	1.8	10.4
300	2.364	20.0	61.0	2.274	141.9	1.6	10.2

SAMPLE SFAR 53.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.670	11.0	29.7	2.121	132.4	8.2	16.2
5	2.625	16.0	49.5	2.143	133.7	7.3	15.4
10	2.600	16.5	51.3	2.156	134.4	6.8	14.9
15	2.582	19.0	53.1	2.165	135.0	6.4	14.5
25	2.556	19.0	53.6	2.176	135.8	5.9	14.1
35	2.535	19.0	54.1	2.186	136.4	5.4	13.7
50	2.512	19.0	54.6	2.196	137.1	5.0	13.2
75	2.485	19.5	56.6	2.209	137.9	4.4	12.7
100	2.466	20.0	56.3	2.218	138.4	4.0	12.4
125	2.452	20.0	56.9	2.225	138.8	3.7	12.1
150	2.440	21.0	62.1	2.251	139.2	3.5	11.9
175	2.431	21.0	62.3	2.256	139.5	3.3	11.7
200	2.423	21.0	62.5	2.259	139.7	3.1	11.5
225	2.416	22.0	65.7	2.241	139.9	3.0	11.5
250	2.412	22.0	66.6	2.244	140.0	2.9	11.3
300	2.404	22.0	65.0	2.246	140.3	2.7	11.2

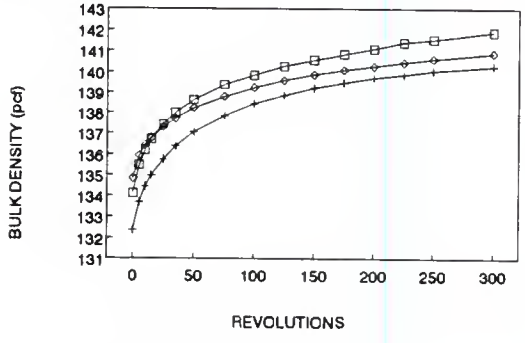
SAMPLE SFAR 53.12

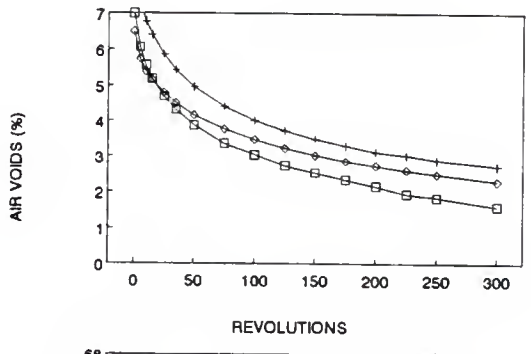
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.621	10.5	28.9	2.161	134.8	6.5	14.6
5	2.578	20.0	55.0	2.178	135.9	5.7	13.9
10	2.558	20.5	57.8	2.187	135.4	5.4	13.6
15	2.545	20.5	58.1	2.192	136.8	5.2	13.4
25	2.524	20.6	59.5	2.200	137.3	4.8	13.1
35	2.508	20.6	59.8	2.207	137.7	4.5	12.8
50	2.488	21.0	60.9	2.215	138.2	4.1	12.5
75	2.465	21.0	61.5	2.224	138.8	3.8	12.1
100	2.449	21.5	63.3	2.231	139.2	3.5	11.9
125	2.436	21.6	64.6	2.237	139.6	3.2	11.6
150	2.424	22.3	66.4	2.241	139.9	3.0	11.5
175	2.415	22.3	66.6	2.245	140.1	2.9	11.3
200	2.408	22.3	66.8	2.248	140.3	2.7	11.2
225	2.401	22.5	67.6	2.251	140.4	2.6	11.1
250	2.394	22.5	67.8	2.254	140.6	2.5	11.0
300	2.383	22.5	68.1	2.256	140.8	2.3	10.8

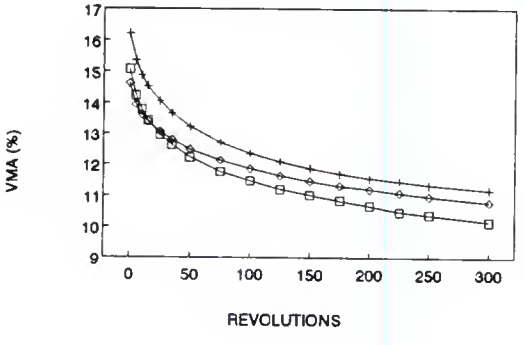
AVERAGE

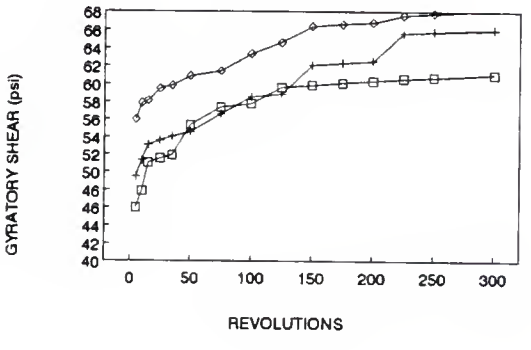
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	29.6	2.144	133.8	7.2	92.8	15.3
5	50.5	2.164	135.0	6.4	93.6	14.8
10	52.3	2.174	135.7	5.9	94.1	14.1
15	54.1	2.182	136.2	5.6	94.4	13.8
25	54.9	2.193	136.8	5.1	94.9	13.4
35	56.5	2.201	137.4	4.7	95.3	13.0
50	56.9	2.211	136.0	4.3	95.7	12.6
75	56.5	2.222	136.7	3.6	96.2	12.2
100	59.9	2.230	139.2	3.5	96.5	11.9
125	61.0	2.237	139.6	3.2	96.8	11.6
150	62.8	2.241	139.9	3.0	97.0	11.4
175	63.0	2.246	140.1	2.8	97.2	11.3
200	63.2	2.249	140.4	2.7	97.3	11.1
225	64.6	2.253	140.6	2.5	97.5	11.0
250	64.8	2.256	140.7	2.4	97.6	10.9
300	65.1	2.260	141.0	2.2	97.8	10.7

MIX ID: SFAR









MIX ID: CABBAGE GROVE (FL3)

GTM COMPACTION

RICE: 2.342
BSG(Agg) 2.475
BINDER % 6.2

AVERAGE BSG(FINAL) 2.185
AVERAGE HEIGHT(FINAL) 2.643

SAMPLE SCAR 62.10

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.086	9.5	22.2	1.864	116.3	20.4	29.3
1	2.961			1.943	121.2	17.0	26.4
2	2.924			1.968	122.8	16.0	25.4
3	2.892			1.989	124.1	15.1	24.6
4	2.843			2.022	126.2	13.7	23.4
5	2.804	16	41.2	2.052	128.0	12.4	22.2
6	2.777			2.072	129.3	11.5	21.5
7	2.753			2.090	130.4	10.6	20.8
8	2.732			2.106	131.4	10.1	20.2
9	2.713			2.121	132.3	9.5	19.8
10	2.695	18	42.8	2.135	133.2	8.9	19.1
11	2.681			2.146	133.9	8.4	18.7
12	2.667			2.157	134.6	7.9	18.2
13	2.655			2.167	135.2	7.5	17.9
14	2.644			2.176	135.8	7.1	17.5
15	2.633	16.5	45.2	2.185	136.3	6.7	17.2

SAMPLE SCAR 62.11

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.216	6.5	19.1	1.793	111.9	23.5	32.1
1	3.070			1.878	117.3	19.6	28.8
2	2.955			1.952	121.8	16.8	26.0
3	2.863			2.001	124.9	14.8	24.2
4	2.844			2.029	126.8	13.4	23.1
5	2.806	17	43.7	2.056	128.3	12.2	22.1
6	2.782			2.074	129.4	11.3	21.4
7	2.765			2.090	130.4	10.7	20.8
8	2.741			2.105	131.3	10.1	20.2
9	2.723			2.119	132.2	9.5	19.7
10	2.706	16.5	44.0	2.132	133.0	9.0	19.2
11	2.691			2.144	133.8	8.5	18.7
12	2.678			2.154	134.4	8.0	18.4
13	2.666			2.164	135.0	7.6	18.0
14	2.655			2.173	135.6	7.2	17.6
15	2.644	17	46.4	2.182	136.2	6.8	17.3

SAMPLE SCAR 62.12

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.223	6	17.9	1.801	112.4	23.1	31.7
1	3.080			1.885	117.6	19.3	28.8
2	2.970			1.956	122.0	16.5	25.9
3	2.905			1.999	124.7	14.7	24.3
4	2.860			2.030	126.7	13.5	23.1
5	2.825	16	40.9	2.055	128.2	12.2	22.1
6	2.801			2.073	129.3	11.5	21.4
7	2.778			2.090	130.4	10.6	20.8
8	2.758			2.105	131.4	10.1	20.2
9	2.740			2.119	132.2	9.5	19.7
10	2.723	16.5	43.7	2.132	133.0	9.0	19.2
11	2.709			2.143	133.7	8.5	18.8
12	2.695			2.154	134.4	8.0	18.4
13	2.683			2.164	135.0	7.6	18.0
14	2.672			2.173	135.6	7.2	17.7
15	2.662	10	27.1	2.181	136.1	6.9	17.3

SAMPLE SCAR 62.13

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.268	9	19.9	1.786	110.2	24.6	33.1
1	3.112			1.885	115.7	20.8	29.7
2	2.998			1.925	120.1	17.8	27.0
3	2.923			1.978	123.2	15.7	25.2
4	2.874			2.008	125.3	14.3	23.9
5	2.833	17.5	44.8	2.037	127.1	13.0	22.8
6	2.805			2.058	128.4	12.1	22.0
7	2.780			2.076	129.6	11.4	21.3
8	2.757			2.093	130.6	10.8	20.7
9	2.736			2.110	131.6	9.9	20.1
10	2.717	17.5	46.5	2.124	132.6	9.3	19.5
11	2.701			2.137	133.3	8.8	19.0
12	2.687			2.146	134.0	8.3	18.6
13	2.673			2.159	134.7	7.8	18.2
14	2.661			2.169	135.3	7.4	17.8
15	2.650	16	49.0	2.178	135.9	7.0	17.5

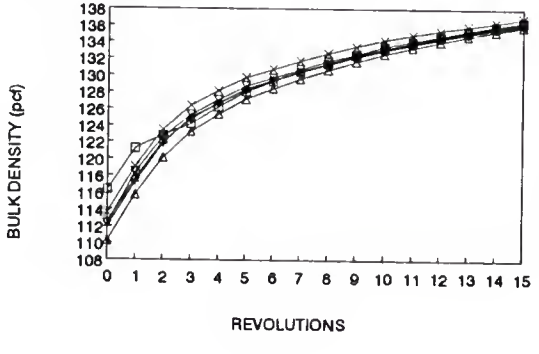
SAMPLE SCAR 62.14

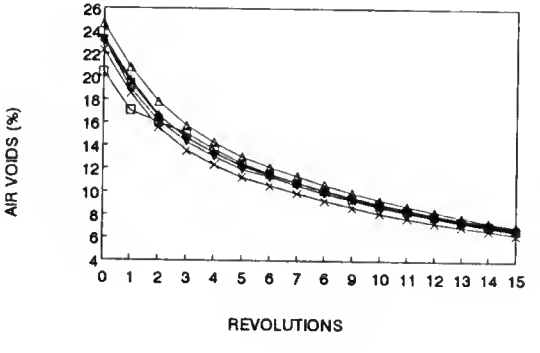
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.193	6	18.1	1.820	113.6	22.3	31.0
1	3.046			1.908	119.1	18.5	27.7
2	2.936			1.976	123.4	15.9	25.8
3	2.870			2.025	126.4	13.5	23.3
4	2.830			2.054	128.1	12.3	22.2
5	2.796	16.5	42.6	2.079	129.7	11.2	21.2
6	2.774			2.095	130.7	10.5	20.6
7	2.753			2.111	131.7	9.9	20.0
8	2.734			2.126	132.6	9.2	19.4
9	2.717			2.139	133.5	8.7	18.9
10	2.701	16.5	44.1	2.152	134.3	8.1	18.5
11	2.688			2.161	134.9	7.7	18.1
12	2.676			2.170	135.4	7.3	17.8
13	2.666			2.176	135.9	7.0	17.4
14	2.659			2.185	135.4	6.7	17.2
15	2.649	16.5	44.9	2.194	135.9	6.3	16.8

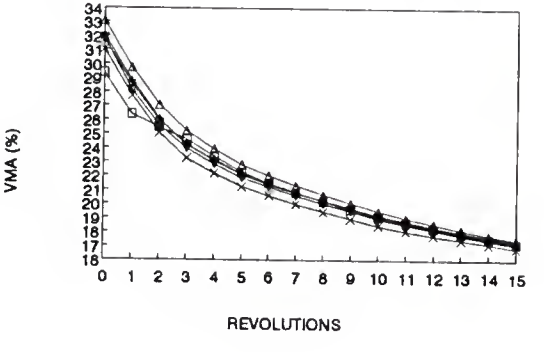
SAMPLE SCAR 62.15

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.185	6	18.1	1.798	112.2	23.2	31.6
1	3.018			1.898	118.4	19.0	28.1
2	2.918			1.964	122.6	16.1	25.6
3	2.854			2.007	125.2	14.3	23.9
4	2.813			2.036	127.1	13.1	22.8
5	2.777	17.5	45.5	2.063	128.7	11.9	21.8
6	2.756			2.078	129.7	11.3	21.2
7	2.734			2.095	130.7	10.5	20.6
8	2.714			2.110	131.7	9.9	20.0
9	2.697			2.124	132.5	9.3	19.5
10	2.676	17	45.8	2.139	133.5	8.7	18.9
11	2.665			2.148	134.1	8.2	18.5
12	2.652			2.156	134.6	7.8	18.1
13	2.640			2.170	135.4	7.4	17.8
14	2.629			2.179	135.9	7.0	17.4
15	2.619	17	46.8	2.187	136.5	6.6	17.1

MIX ID: CABBAGE GROVE (FL3)







MIX ID: CABBAGE GROVE (FL3)

GTM DENSIFICATION

RICE:	2.342	BSGcomp	2.165
BSG(Agg)	2.475	HTcomp	2.643
BINDER %	6.2	REVcomp	15

SAMPLE SCAR62.16

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.600	12.0	33.3	2.221	138.6	5.2	15.8
5	2.585	18.0	50.6	2.237	139.6	4.5	15.2
10	2.546	18.0	51.0	2.248	140.1	4.1	14.9
15	2.535	18.5	52.7	2.250	140.4	3.9	14.7
25	2.514	18.5	53.1	2.259	141.0	3.5	14.4
35	2.499	19.0	54.9	2.266	141.4	3.3	14.1
50	2.482	19.0	55.2	2.273	141.8	2.9	13.9
75	2.461	19.0	55.7	2.282	142.4	2.5	13.5
100	2.443	19.0	56.1	2.290	142.9	2.2	13.2
125	2.428	18.5	56.0	2.297	143.3	1.9	12.9
150	2.419	18.5	55.5	2.303	143.7	1.7	12.7
175	2.404	18.5	55.5	2.307	144.0	1.5	12.5
200	2.394	18.5	55.6	2.312	144.3	1.3	12.4
225	2.384	18.5	56.0	2.316	144.5	1.1	12.2
250	2.376	18.5	56.2	2.320	144.8	0.9	12.1
300	2.362	18.5	56.5	2.326	145.1	0.7	11.8

SAMPLE SCAR62.17

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.659	12.0	32.6	2.172	135.5	7.3	17.7
5	2.612	18.0	49.7	2.195	136.9	6.3	16.8
10	2.587	19.0	53.0	2.207	137.7	5.8	16.4
15	2.569	19.0	53.4	2.215	138.2	5.4	16.0
25	2.542	19.0	53.9	2.228	139.0	4.9	15.5
35	2.521	19.0	54.4	2.238	139.7	4.4	15.2
50	2.498	19.0	54.9	2.250	140.4	3.9	14.7
75	2.470	19.0	55.3	2.263	141.2	3.4	14.2
100	2.450	19.0	55.8	2.273	141.8	3.0	13.9
125	2.434	19.0	56.3	2.280	142.3	2.6	13.6
150	2.422	19.0	56.8	2.286	142.7	2.4	13.4
175	2.412	19.0	56.8	2.291	143.0	2.2	13.2
200	2.403	19.0	57.1	2.295	143.2	2.0	13.0
225	2.395	19.0	57.2	2.299	143.5	1.8	12.9
250	2.388	19.0	57.4	2.303	143.7	1.7	12.7
300	2.377	19.0	57.7	2.308	144.0	1.5	12.5

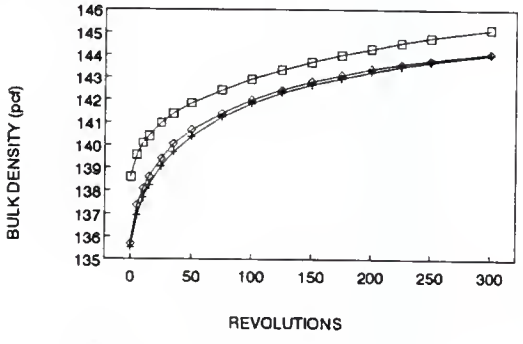
SAMPLE SCAR62.18

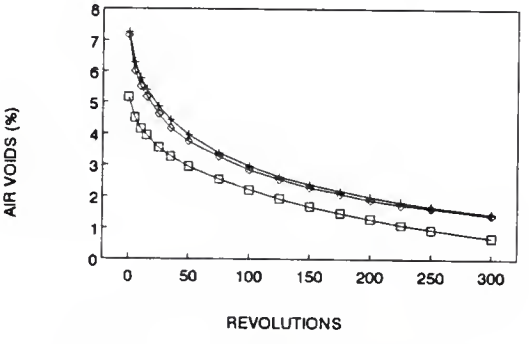
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.656	11.5	31.2	2.174	135.7	7.2	17.6
5	2.608	19.0	52.7	2.201	137.4	6.0	16.6
10	2.580	19.0	53.1	2.213	138.1	5.5	16.1
15	2.564	19.0	53.3	2.221	138.6	5.2	15.8
25	2.539	19.0	54.0	2.234	139.4	4.6	15.3
35	2.518	19.0	54.4	2.244	140.1	4.2	14.9
50	2.499	19.0	54.9	2.254	140.7	3.8	14.6
75	2.476	19.0	55.4	2.266	141.4	3.3	14.1
100	2.457	19.0	55.8	2.275	142.0	2.8	13.8
125	2.443	19.0	56.1	2.283	142.4	2.5	13.5
150	2.431	18.5	54.9	2.289	142.8	2.3	13.3
175	2.422	18.5	55.1	2.293	143.1	2.1	13.1
200	2.413	18.5	55.3	2.298	143.4	1.9	12.9
225	2.406	18.5	55.5	2.301	143.6	1.7	12.8
250	2.401	18.5	55.6	2.304	143.8	1.6	12.7
300	2.391	18.5	55.8	2.309	144.1	1.4	12.5

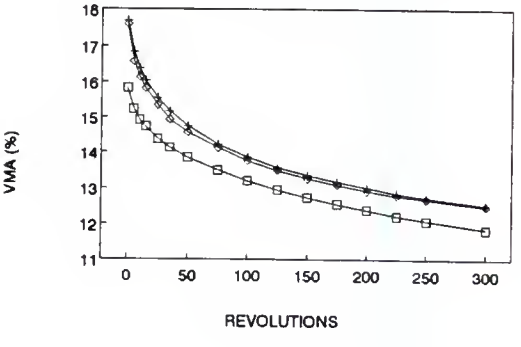
AVERAGE

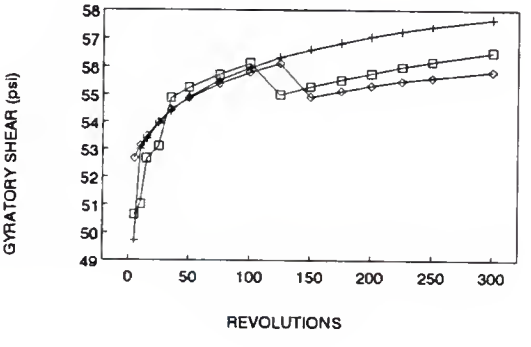
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	32.4	2.189	136.6	6.5	93.5	17.0
5	51.0	2.211	138.0	5.6	94.4	16.2
10	52.4	2.221	138.6	5.1	94.9	15.8
15	53.2	2.229	139.1	4.8	95.2	15.5
25	53.7	2.240	139.8	4.3	95.7	15.1
35	54.6	2.250	140.4	3.9	96.1	14.7
50	55.0	2.259	141.0	3.5	96.5	14.4
75	55.5	2.270	141.7	3.1	96.9	14.0
100	56.0	2.280	142.2	2.7	97.3	13.6
125	56.6	2.287	142.7	2.4	97.6	13.3
150	56.6	2.293	143.1	2.1	97.9	13.1
175	56.6	2.297	143.4	1.9	98.1	12.9
200	56.0	2.302	143.8	1.7	98.3	12.8
225	56.2	2.306	143.9	1.6	98.4	12.6
250	56.4	2.309	144.1	1.4	98.6	12.5
300	56.7	2.314	144.4	1.2	98.8	12.3

MIX ID: SCAR62









MIX ID: CRUSHED PCC (FL4)

GTM COMPACTION

RICE: 2.1036
BSG(Agg) 2.226
BINDER % 5.8

SAMPLE SPAR56.1

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.156	9.5	21.7	1.604	100.1	23.8	32.1
1	2.991			1.692	105.6	19.5	28.4
2	2.876			1.760	109.8	16.3	25.5
3	2.810			1.801	112.4	14.4	23.8
4	2.764			1.831	114.3	12.9	22.5
5	2.728	17	45.0	1.856	115.8	11.8	21.5
6	2.701			1.874	116.9	10.9	20.7
7	2.678			1.892	118.0	10.1	20.0
8	2.656			1.907	119.0	9.4	19.5
9	2.637			1.920	119.8	8.7	18.8
10	2.621	17.5	48.2	1.931	120.5	8.2	18.3
11	2.607			1.942	121.2	7.7	17.8
12	2.595			1.951	121.7	7.3	17.5
13	2.583			1.960	122.3	6.8	17.1
14	2.572			1.968	122.8	6.4	16.7
15	2.563	17.5	49.5	1.975	123.2	6.1	16.4

SAMPLE SPAR56.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.164	10	22.7	1.604	100.1	23.8	32.1
1	3.010			1.697	105.9	19.4	28.2
2	2.901			1.760	109.8	16.3	25.5
3	2.831			1.804	112.6	14.5	23.7
4	2.789			1.831	114.3	13.0	22.3
5	2.752	17.5	45.9	1.856	115.8	11.8	21.5
6	2.727			1.875	116.9	11.0	20.8
7	2.704			1.889	117.8	10.2	20.1
8	2.683			1.903	118.8	9.5	19.5
9	2.663			1.916	119.7	8.8	18.9
10	2.645	17	48.4	1.931	120.5	8.2	18.3
11	2.631			1.941	121.1	7.7	17.9
12	2.617			1.951	121.8	7.2	17.4
13	2.606			1.960	122.3	6.8	17.0
14	2.594			1.969	122.8	6.4	16.7
15	2.583	17	47.5	1.977	123.4	6.0	16.3

SAMPLE SPAR56.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.156	9.5	21.7	1.604	100.1	23.8	32.1
1	2.994			1.690	105.5	19.6	28.5
2	2.884			1.755	109.5	16.6	25.7
3	2.813			1.799	112.3	14.5	23.9
4	2.767			1.829	114.1	13.1	22.6
5	2.731	17	44.9	1.853	115.6	11.9	21.6
6	2.703			1.872	116.8	11.0	20.8
7	2.678			1.891	118.0	10.1	20.0
8	2.658			1.904	118.8	9.5	19.4
9	2.640			1.917	119.6	8.9	18.9
10	2.624	17.5	48.1	1.929	120.4	8.3	18.4
11	2.610			1.939	121.0	7.8	17.9
12	2.599			1.947	121.5	7.4	17.6
13	2.588			1.956	122.0	7.0	17.2
14	2.578			1.963	122.5	6.7	16.9
15	2.569	17.5	49.2	1.970	122.9	6.4	16.6

SAMPLE SPAR56.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.208	10	22.5	1.562	99.7	24.8	33.1
1	3.045			1.668	104.0	20.8	29.5
2	2.922			1.736	108.5	17.5	26.5
3	2.845			1.783	111.3	15.2	24.5
4	2.798			1.815	113.2	13.7	23.2
5	2.757	17.5	45.6	1.840	114.8	12.5	22.1
6	2.729			1.859	116.0	11.6	21.3
7	2.703			1.877	117.1	10.8	20.6
8	2.679			1.894	118.2	10.0	19.9
9	2.660			1.907	119.0	9.5	19.3
10	2.642	17.5	47.6	1.920	119.8	8.7	18.7
11	2.626			1.932	120.6	8.2	18.2
12	2.612			1.942	121.2	7.7	17.8
13	2.600			1.951	121.6	7.2	17.4
14	2.589			1.960	122.3	6.8	17.1
15	2.578	17.5	49.0	1.966	122.8	6.4	16.7

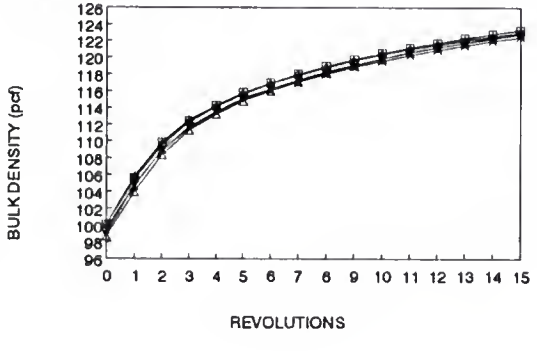
SAMPLE SPAR56.5

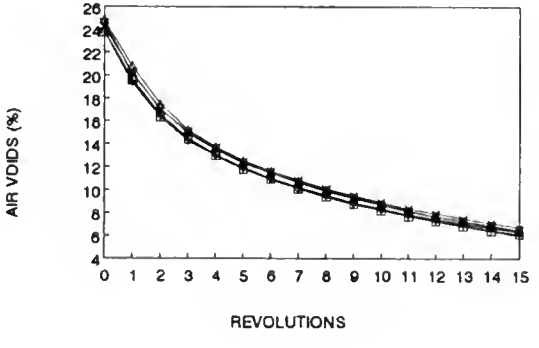
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.189	9	20.4	1.594	99.5	24.2	32.5
1	3.031			1.677	104.7	20.3	29.0
2	2.911			1.746	109.0	17.0	26.1
3	2.845			1.787	111.5	15.1	24.4
4	2.798			1.817	113.4	13.8	23.1
5	2.759	19	49.7	1.843	115.0	12.4	22.0
6	2.734			1.859	116.0	11.6	21.3
7	2.710			1.878	117.1	10.8	20.8
8	2.688			1.891	118.0	10.1	20.0
9	2.669			1.905	118.9	9.5	19.4
10	2.653	19	51.7	1.916	119.6	8.9	18.9
11	2.637			1.926	120.3	8.4	18.4
12	2.624			1.937	120.9	7.9	18.0
13	2.612			1.946	121.4	7.5	17.6
14	2.601			1.954	122.0	7.1	17.3
15	2.591	16.5	51.5	1.962	122.4	6.7	17.0

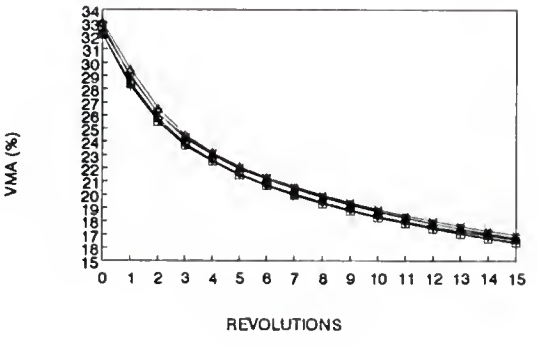
SAMPLE SPAR56.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.168	10.5	23.9	1.587	99.0	24.5	32.8
1	2.992			1.681	104.9	20.1	28.9
2	2.882			1.745	108.9	17.1	26.2
3	2.806			1.791	111.7	14.9	24.2
4	2.764			1.819	113.5	13.5	23.0
5	2.725	18	47.7	1.845	115.1	12.3	21.9
6	2.699			1.863	116.3	11.4	21.2
7	2.674			1.880	117.3	10.8	20.4
8	2.652			1.895	118.3	9.9	19.8
9	2.634			1.909	119.1	9.3	19.2
10	2.617	17.5	48.3	1.921	119.9	8.7	18.7
11	2.601			1.933	120.6	8.1	18.2
12	2.589			1.942	121.2	7.7	17.8
13	2.577			1.951	121.8	7.2	17.4
14	2.566			1.960	122.3	6.8	17.0
15	2.556	17.5	49.4	1.966	122.8	6.4	16.7

MIX ID: CRUSHED PCC (FL4)







MIX ID: CRUSHED PCC (FL4) GTM DENSIFICATION

RICE:	2.1036	BSGcomp	1.97
BSG(Agg)	2.226	HTcomp	2.573
BINDER %	5.8	REVcomp	15

SAMPLE SPAR56.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.567	11.0	30.9	1.975	123.2	6.1	16.4
5	2.524	17.5	30.0	1.995	124.5	5.1	15.6
10	2.507	17.5	50.4	2.003	125.0	4.6	15.2
15	2.492	17.5	50.7	2.011	125.5	4.4	14.9
25	2.473	17.5	51.1	2.020	126.0	4.0	14.5
35	2.458	17.5	51.4	2.027	126.5	3.6	14.2
50	2.440	17.5	51.8	2.036	127.0	3.2	13.9
75	2.416	17.5	52.2	2.046	127.7	2.7	13.4
100	2.400	17.5	52.6	2.053	128.2	2.3	13.0
125	2.386	17.5	52.9	2.062	128.8	2.0	12.8
150	2.374	17.5	53.2	2.067	129.0	1.7	12.5
175	2.364	17.5	53.4	2.072	129.5	1.5	12.3
200	2.356	17.5	53.6	2.076	129.5	1.3	12.1
225	2.347	17.5	53.8	2.080	129.8	1.1	12.0
250	2.339	18.0	55.5	2.084	130.1	0.9	11.8
300	2.327	18.5	57.4	2.090	130.4	0.8	11.6

SAMPLE SPAR56.8

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.584	10.5	29.3	1.982	122.4	6.7	17.0
5	2.538	16.0	51.2	1.986	123.9	5.6	16.0
10	2.519	18.0	51.6	1.996	124.5	5.1	15.6
15	2.500	18.0	52.0	2.006	125.1	4.7	15.1
25	2.482	17.5	50.9	2.015	125.7	4.2	14.7
35	2.465	17.5	51.2	2.024	126.3	3.8	14.4
50	2.444	17.5	51.7	2.036	127.0	3.5	13.9
75	2.417	17.5	52.2	2.049	127.8	2.9	13.3
100	2.398	17.5	52.7	2.059	128.5	2.1	12.9
125	2.382	17.5	53.0	2.067	129.0	1.7	12.5
150	2.369	17.5	53.3	2.074	129.4	1.4	12.2
175	2.359	17.0	52.0	2.079	129.7	1.2	12.0
200	2.349	17.0	52.2	2.084	130.1	0.9	11.8
225	2.339	17.5	54.0	2.090	130.4	0.7	11.6
250	2.332	18.0	55.7	2.090	130.9	0.5	11.4
300	2.321	18.0	56.0	2.099	131.0	0.2	11.2

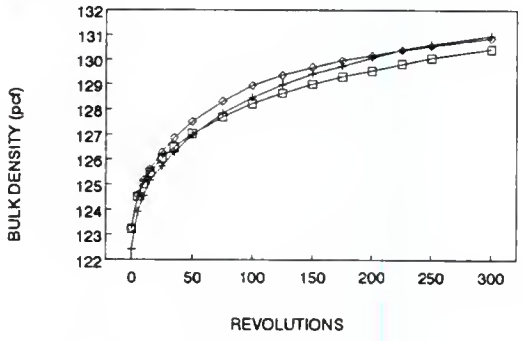
SAMPLE SPAR56.9

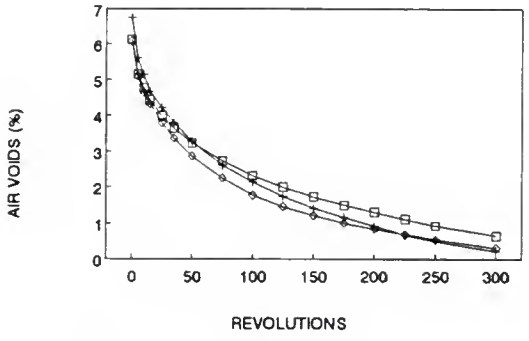
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.566	11.0	30.9	1.975	123.3	6.1	16.4
5	2.522	16.0	51.5	1.998	124.8	5.1	15.5
10	2.502	16.0	51.9	2.006	125.2	4.6	15.1
15	2.488	16.0	52.2	2.013	125.6	4.3	14.8
25	2.465	17.5	51.2	2.024	126.3	3.8	14.4
35	2.446	17.5	51.6	2.033	126.8	3.4	14.0
50	2.424	17.5	52.1	2.043	127.5	2.9	13.5
75	2.397	17.5	52.7	2.056	128.3	2.2	13.0
100	2.378	18.0	54.7	2.056	128.9	1.8	12.6
125	2.362	18.0	55.0	2.075	129.4	1.5	12.3
150	2.351	18.5	55.6	2.078	129.7	1.2	12.0
175	2.342	18.5	57.0	2.083	130.0	1.0	11.9
200	2.335	19.0	56.7	2.086	130.2	0.8	11.7
225	2.328	19.0	58.9	2.089	130.4	0.7	11.6
250	2.322	19.5	60.6	2.092	130.6	0.5	11.5
300	2.312	20.5	64.0	2.097	130.9	0.3	11.3

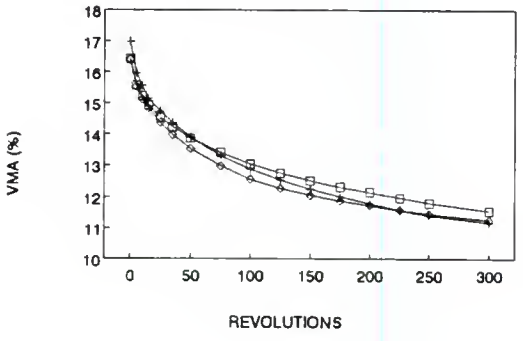
AVERAGE

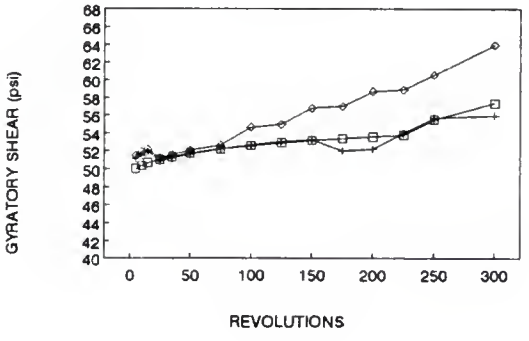
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	30.4	1.971	123.0	6.3	93.7	16.6
5	50.9	1.992	124.3	5.3	94.7	15.7
10	51.3	2.002	124.9	4.8	95.2	15.3
15	51.8	2.010	125.4	4.5	95.5	15.0
25	51.1	2.019	126.0	4.0	96.0	14.5
35	51.4	2.028	126.5	3.6	96.4	14.2
50	51.8	2.036	127.2	3.1	96.9	13.8
75	52.4	2.050	127.9	2.5	97.5	13.2
100	53.3	2.060	128.5	2.1	97.9	12.8
125	53.8	2.067	129.0	1.7	98.3	12.5
150	54.4	2.073	129.4	1.4	98.6	12.3
175	54.1	2.078	129.7	1.2	98.8	12.1
200	54.8	2.082	129.9	1.0	99.0	11.9
225	55.9	2.086	130.2	0.8	99.2	11.7
250	57.3	2.090	130.4	0.7	99.3	11.6
300	59.1	2.095	130.7	0.4	99.6	11.3

MIX ID: SPAR









MIX ID: ALABAMA SMA (FL5)

GTM COMPACTION

RICE: 2.547
BSG(Agg) 2.741
BINDER % 5.0

SAMPLE SAAR 50.1

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.124	7.5	17.3	1.945	121.4	23.6	32.6
1	2.966			2.047	127.8	19.6	29.0
2	2.857			2.127	132.7	16.5	26.3
3	2.796			2.173	135.6	14.7	24.7
4	2.753			2.207	137.7	13.3	23.5
5	2.719	17.5	46.4	2.235	139.5	12.3	22.5
6	2.694			2.255	140.7	11.4	21.6
7	2.671			2.275	142.0	10.7	21.2
8	2.652			2.291	143.0	10.0	20.6
9	2.636			2.305	143.8	9.5	20.1
10	2.620	16	49.6	2.319	144.7	8.9	19.6
11	2.606			2.332	145.5	8.5	19.2
12	2.594			2.343	146.2	8.0	18.8
13	2.583			2.352	146.8	7.6	18.5
14	2.573			2.362	147.4	7.3	18.1
15	2.565	16	50.6	2.369	147.8	7.0	17.9

SAMPLE SAAR 50.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.086	6	16.7	1.972	123.1	22.6	31.6
1	2.938			2.071	129.3	18.7	28.2
2	2.841			2.142	133.7	15.9	25.8
3	2.781			2.186	136.6	14.1	24.2
4	2.743			2.219	138.4	12.9	23.1
5	2.715	16	47.8	2.242	139.9	12.0	22.3
6	2.693			2.260	141.0	11.3	21.7
7	2.672			2.278	142.1	10.6	21.1
8	2.655			2.292	143.0	10.0	20.6
9	2.639			2.306	143.9	9.5	20.1
10	2.624	16	49.5	2.319	144.7	8.9	19.6
11	2.611			2.331	145.4	8.5	19.2
12	2.599			2.342	146.1	8.1	18.8
13	2.589			2.351	146.7	7.7	18.5
14	2.579			2.360	147.3	7.3	18.2
15	2.569	16	50.6	2.369	147.8	7.0	17.9

SAMPLE SAAR 50.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.114	7.5	17.4	1.958	122.2	23.1	32.1
1	2.974			2.051	128.0	19.5	28.9
2	2.874			2.122	132.4	16.7	26.5
3	2.797			2.180	136.1	14.4	24.4
4	2.750			2.216	138.4	12.9	23.1
5	2.706	16	42.7	2.254	140.6	11.5	21.9
6	2.680			2.276	142.0	10.7	21.1
7	2.655			2.297	143.3	9.8	20.4
8	2.636			2.314	144.4	9.1	19.8
9	2.618			2.331	145.5	8.5	19.2
10	2.600	16	44.4	2.346	146.4	7.9	18.7
11	2.585			2.359	147.2	7.4	18.2
12	2.572			2.371	148.0	6.9	17.8
13	2.560			2.382	148.7	6.5	17.4
14	2.549			2.393	149.3	6.1	17.1
15	2.539	16	45.5	2.402	149.9	5.7	16.7

SAMPLE SAAR 50.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.147	10	22.9	1.927	120.2	24.4	33.2
1	2.995			2.025	126.3	20.5	29.8
2	2.889			2.113	131.9	17.0	26.7
3	2.795			2.189	135.4	14.6	24.6
4	2.745			2.209	137.8	13.3	23.4
5	2.708	16	48.0	2.241	139.8	12.0	22.3
6	2.679			2.263	141.2	11.1	21.6
7	2.655			2.284	142.5	10.3	20.8
8	2.633			2.305	143.7	9.6	20.2
9	2.613			2.319	144.7	9.0	19.6
10	2.596	16	50.0	2.334	145.6	8.4	19.1
11	2.584			2.347	146.4	7.9	18.7
12	2.570			2.359	147.2	7.4	18.2
13	2.557			2.371	148.0	6.9	17.8
14	2.546			2.382	148.6	6.5	17.5
15	2.536	16	51.2	2.391	149.2	6.1	17.1

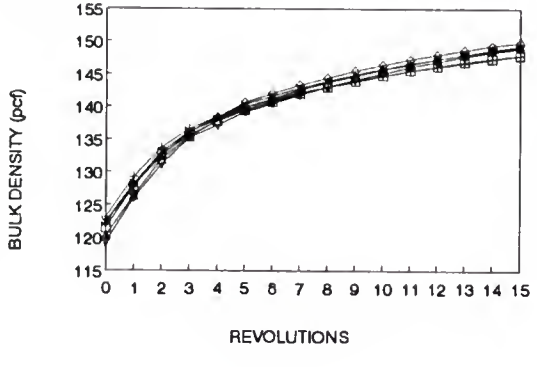
SAMPLE SAAR 50.5

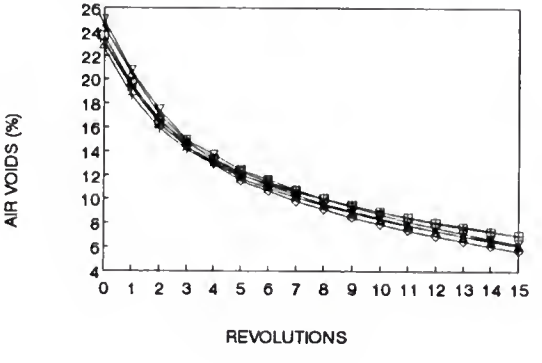
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.098	10	25.3	1.959	122.3	25.1	32.1
1	2.955			2.054	128.2	19.3	28.6
2	2.847			2.132	133.0	16.3	26.1
3	2.782			2.182	136.2	14.3	24.4
4	2.743			2.213	138.1	13.1	23.3
5	2.700	20	53.5	2.248	140.3	11.7	22.1
6	2.674			2.270	141.7	10.9	21.3
7	2.652			2.289	142.8	10.1	20.7
8	2.633			2.305	143.9	9.5	20.1
9	2.613			2.321	144.9	8.9	19.5
10	2.599	20	55.5	2.336	145.7	8.3	19.0
11	2.585			2.348	146.5	7.8	18.6
12	2.573			2.359	147.2	7.4	18.2
13	2.561			2.370	147.9	6.9	17.8
14	2.551			2.380	148.5	6.6	17.5
15	2.542	20	56.8	2.388	149.0	6.2	17.2

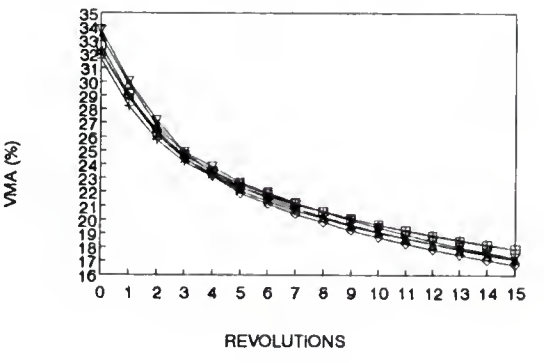
SAMPLE SAAR 50.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.161	10.5	25.8	1.911	119.3	25.0	33.6
1	3.011			2.010	126.0	20.7	30.0
2	2.893			2.102	131.1	17.5	27.2
3	2.806			2.167	135.2	14.9	24.9
4	2.756			2.198	137.2	13.7	23.8
5	2.725	19	50.3	2.230	139.2	12.4	22.7
6	2.701			2.251	140.3	11.6	22.0
7	2.675			2.273	141.8	10.8	21.2
8	2.653			2.292	143.0	10.0	20.6
9	2.633			2.309	144.1	9.3	20.0
10	2.615	19	52.4	2.325	145.1	8.7	19.4
11	2.598			2.340	146.0	8.1	18.9
12	2.584			2.353	146.8	7.6	18.5
13	2.570			2.366	147.6	7.1	18.0
14	2.556			2.377	148.3	6.7	17.6
15	2.547	19	53.8	2.387	148.9	6.3	17.3

SAAR50







MIX ID: ALABAMA SMA (FLS) GTM DENSIFICATION

RICE:	2.547	BSGcomp	2.384
BSG(Agg)	2.741	HTcomp	2.549
BINDER %	5	REVcomp	15

SAMPLE SAAR 50.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.532	12.0	34.2	2.400	149.8	5.8	18.8
5	2.486	18.5	53.7	2.422	151.1	4.9	18.1
10	2.464	19.0	55.8	2.432	151.8	4.5	15.7
15	2.449	18.5	54.5	2.439	152.2	4.2	15.5
25	2.425	18.0	53.6	2.451	152.9	3.8	15.1
35	2.410	18.5	55.4	2.456	153.4	3.5	14.8
50	2.393	18.5	55.8	2.466	153.9	3.2	14.5
75	2.375	18.5	56.2	2.474	154.4	2.9	14.2
100	2.362	18.5	56.5	2.481	154.8	2.6	14.0
125	2.353	19.0	58.3	2.485	155.1	2.4	13.9
150	2.346	19.0	58.4	2.486	155.3	2.3	13.8
175	2.342	19.0	58.5	2.490	155.4	2.2	13.7
200	2.336	19.5	60.2	2.493	155.6	2.1	13.6
225	2.332	20.0	61.9	2.495	155.7	2.1	13.5
250	2.329	20.0	62.0	2.496	155.8	2.0	13.5
300	2.323	20.5	63.7	2.499	155.9	1.9	13.4

SAMPLE SAAR 50.8

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.553	11.5	32.5	2.360	148.5	6.5	17.5
5	2.503	20.0	57.7	2.406	150.1	5.5	16.6
10	2.482	20.0	58.1	2.417	150.8	5.1	16.2
15	2.466	20.0	58.5	2.424	151.5	4.8	16.0
25	2.449	20.0	58.9	2.434	151.9	4.4	15.6
35	2.435	20.0	59.3	2.441	152.3	4.1	15.4
50	2.416	20.0	59.7	2.450	152.9	3.8	15.1
75	2.401	20.0	60.1	2.459	153.4	3.5	14.8
100	2.389	20.0	60.4	2.466	153.8	3.2	14.6
125	2.381	20.0	60.6	2.469	154.1	3.0	14.4
150	2.374	20.0	60.8	2.473	154.3	2.9	14.3
175	2.368	20.0	60.9	2.476	154.5	2.8	14.2
200	2.364	20.5	62.6	2.476	154.6	2.7	14.1
225	2.361	21.0	64.2	2.480	154.7	2.6	14.1
250	2.357	21.0	64.3	2.482	154.9	2.6	14.0
300	2.351	21.0	64.5	2.485	155.1	2.4	13.9

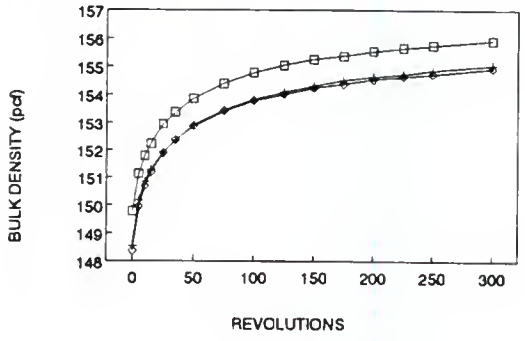
SAMPLE SAAR 50.9

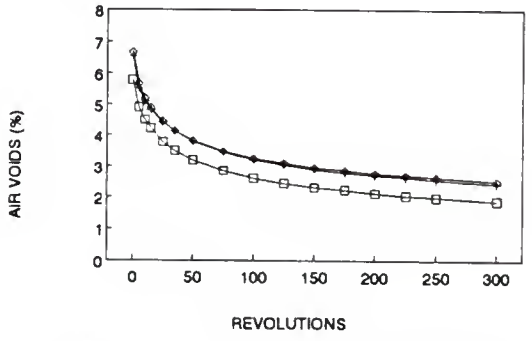
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.556	11.5	32.5	2.377	148.4	6.7	17.6
5	2.508	19.0	54.7	2.403	149.9	5.7	16.7
10	2.486	20.0	56.1	2.415	150.7	5.2	16.3
15	2.471	20.0	56.4	2.423	151.2	4.9	16.0
25	2.450	20.0	56.9	2.434	151.9	4.4	15.7
35	2.435	20.0	59.5	2.442	152.4	4.1	15.4
50	2.420	20.0	59.8	2.450	152.9	3.8	15.1
75	2.403	20.0	60.1	2.459	153.4	3.5	14.8
100	2.392	20.0	60.3	2.464	153.8	3.2	14.6
125	2.385	21.0	63.5	2.466	154.0	3.1	14.5
150	2.378	21.0	63.7	2.472	154.2	2.9	14.3
175	2.374	21.0	63.8	2.474	154.4	2.9	14.5
200	2.369	21.0	64.0	2.477	154.5	2.8	14.2
225	2.366	21.0	64.0	2.478	154.6	2.7	14.1
250	2.363	21.0	64.1	2.480	154.7	2.6	14.1
300	2.357	21.5	65.8	2.483	154.9	2.5	13.9

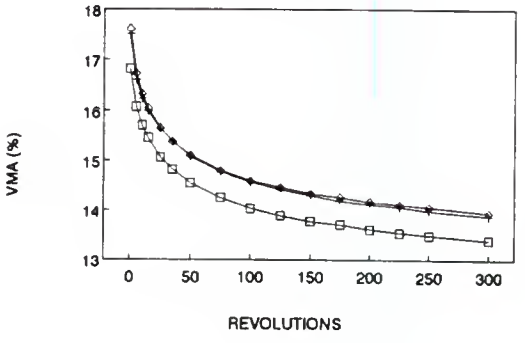
AVERAGE

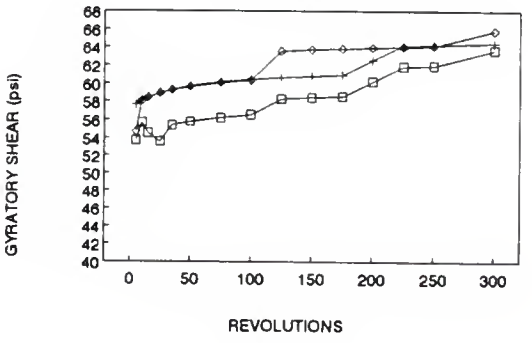
REV	Gs	BSG	B DENS	A.V	%TMD	VMA
0	33.1	2.386	148.9	6.3	93.7	17.5
5	55.3	2.410	150.4	5.4	94.8	16.5
10	57.3	2.421	151.1	4.9	95.1	16.1
15	57.1	2.429	151.6	4.6	95.4	15.8
25	57.1	2.440	152.2	4.2	95.8	15.4
35	58.0	2.447	152.7	3.9	96.1	15.2
50	58.4	2.455	153.2	3.6	96.4	14.9
75	58.8	2.464	153.8	3.3	96.7	14.6
100	59.1	2.470	154.1	3.0	97.0	14.4
125	60.8	2.474	154.4	2.9	97.1	14.2
150	61.0	2.478	154.6	2.7	97.3	14.1
175	61.1	2.480	154.8	2.6	97.4	14.0
200	62.3	2.483	154.9	2.5	97.5	14.0
225	63.4	2.484	155.0	2.5	97.5	13.9
250	63.5	2.486	155.1	2.4	97.6	13.8
300	64.7	2.489	155.3	2.3	97.7	13.7

MIX ID: SAAR









MIX ID: CHATTAHOOCHEE RIVER GRAVEL (FL6)

GTM COMPACTION

RICE: 2.47791
BSG(Agg) 2.644
BINDER % 4.7

SAMPLE SGAR47.1

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.066	9	21.0	1.951	121.7	21.5	29.7
1	2.954			2.036	127.2	17.6	26.5
2	2.865			2.101	131.1	15.2	24.3
3	2.812			2.141	133.6	13.6	22.8
4	2.775			2.170	135.4	12.4	21.6
5	2.747	20	52.5	2.192	136.8	11.6	21.0
6	2.727			2.206	137.8	10.9	20.4
7	2.708			2.223	138.7	10.3	19.9
8	2.692			2.236	139.6	9.7	19.4
9	2.679			2.247	140.2	9.3	19.0
10	2.667	20	54.1	2.257	140.9	8.9	18.6
11	2.657			2.266	141.4	8.6	18.3
12	2.648			2.274	141.9	8.2	18.1
13	2.639			2.281	142.4	7.9	17.8
14	2.630			2.289	142.8	7.6	17.5
15	2.621	20	55.1	2.297	143.5	7.3	17.2

SAMPLE SGAR47.2

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.114	9	20.9	1.921	119.9	22.5	30.6
1	2.965			2.017	125.9	18.6	27.3
2	2.857			2.086	130.2	15.8	24.8
3	2.806			2.130	132.9	14.0	23.2
4	2.770			2.159	134.7	12.9	22.2
5	2.739	19	50.1	2.184	136.5	11.9	21.3
6	2.717			2.201	137.4	11.2	20.7
7	2.699			2.216	138.3	10.6	20.1
8	2.682			2.230	139.2	10.0	19.6
9	2.667			2.243	139.9	9.5	19.2
10	2.652	19	51.7	2.255	140.7	9.0	18.7
11	2.640			2.266	141.4	8.6	18.3
12	2.630			2.274	141.9	8.2	18.0
13	2.621			2.282	142.4	7.9	17.7
14	2.613			2.289	142.8	7.6	17.5
15	2.605	20	55.4	2.296	143.3	7.5	17.2

SAMPLE SGAR47.3

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.061	9	21.2	1.953	122.0	21.1	29.5
1	2.924			2.046	127.7	17.4	26.2
2	2.837			2.109	131.6	14.9	24.0
3	2.784			2.149	134.1	13.5	22.5
4	2.748			2.177	135.9	12.1	21.3
5	2.718	20.5	54.4	2.201	137.4	11.2	20.7
6	2.698			2.218	138.4	10.5	20.1
7	2.682			2.231	139.2	10.0	19.6
8	2.666			2.243	139.9	9.5	19.2
9	2.656			2.253	140.6	9.1	18.9
10	2.645	21.5	56.7	2.262	141.2	8.7	18.5
11	2.636			2.270	141.6	8.4	18.2
12	2.628			2.277	142.1	8.1	17.9
13	2.621			2.283	142.4	7.9	17.7
14	2.614			2.289	142.8	7.6	17.5
15	2.607	21.5	59.5	2.295	143.2	7.4	17.3

SAMPLE SGAR47.4

REV	HT.	ARP	Gs	BSG	B DENS	A.V	VMA
0	3.070	9	21.2	1.952	121.8	21.2	29.7
1	2.921			2.051	128.0	17.2	26.1
2	2.840			2.110	131.6	14.9	24.0
3	2.786			2.151	134.2	13.2	22.5
4	2.752			2.177	135.9	12.1	21.5
5	2.724	21	55.6	2.200	137.3	11.2	20.7
6	2.708			2.215	138.1	10.7	20.3
7	2.693			2.225	138.8	10.2	19.8
8	2.680			2.236	139.5	9.8	19.4
9	2.668			2.246	140.1	9.4	19.1
10	2.657	21.5	58.4	2.256	140.7	9.0	18.7
11	2.647			2.264	141.2	8.7	18.4
12	2.637			2.272	141.8	8.3	18.1
13	2.629			2.279	142.2	8.0	17.9
14	2.620			2.287	142.7	7.7	17.6
15	2.613	21.5	59.4	2.293	143.1	7.5	17.4

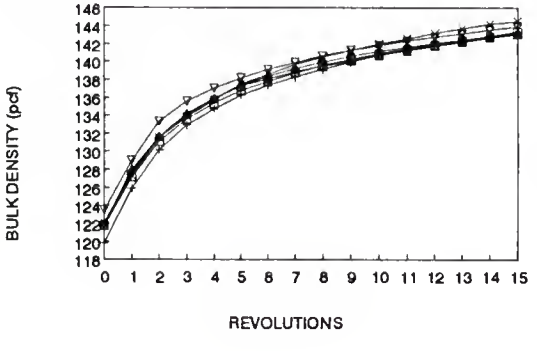
SAMPLE SGAR47.5

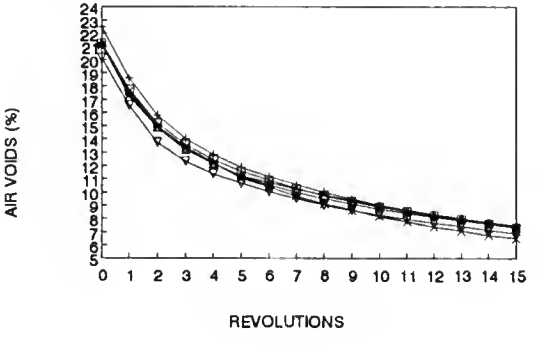
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.044	9.5	22.5	1.956	122.1	21.1	29.5
1	2.916			2.041	127.3	17.6	26.4
2	2.825			2.108	131.5	14.9	24.0
3	2.775			2.148	133.9	13.4	22.7
4	2.737			2.176	135.8	12.2	21.6
5	2.702	19	50.7	2.204	137.5	11.1	20.6
6	2.681			2.221	138.6	10.4	19.9
7	2.661			2.236	139.6	9.7	19.3
8	2.644			2.252	140.5	9.1	18.8
9	2.630			2.264	141.3	8.6	18.4
10	2.617	19	52.4	2.275	142.0	8.2	18.0
11	2.606			2.285	142.6	7.8	17.6
12	2.595			2.295	143.2	7.4	17.3
13	2.586			2.303	143.7	7.1	17.0
14	2.577			2.311	144.2	6.8	16.7
15	2.571	20.3	57.5	2.316	144.5	6.5	16.5

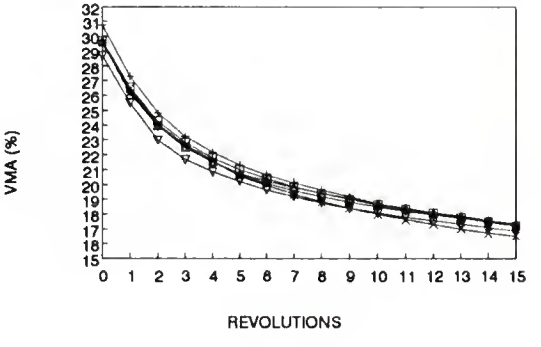
SAMPLE SGAR47.6

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	3.022	9.3	22.7	1.979	123.5	20.1	28.7
1	2.892			2.068	129.0	16.6	25.5
2	2.798			2.137	133.4	13.6	23.0
3	2.752			2.173	135.6	12.3	21.7
4	2.723			2.196	137.0	11.4	20.8
5	2.701	21.3	57.4	2.214	138.1	10.7	20.2
6	2.682			2.230	139.1	10.0	19.6
7	2.667			2.242	139.9	9.5	19.2
8	2.653			2.254	140.6	9.0	18.8
9	2.641			2.264	141.3	8.6	18.4
10	2.631	22	60.3	2.273	141.8	8.5	18.1
11	2.622			2.281	142.3	8.0	17.8
12	2.614			2.288	142.7	7.7	17.5
13	2.607			2.294	143.1	7.4	17.3
14	2.599			2.301	143.6	7.1	17.1
15	2.592	22	61.2	2.307	144.0	6.9	16.8

MIX ID. CHATTAHOOCHEE RIVER GRAVEL (FL6)







MIX ID: CHATTAHOOCHEE RIVER GRAVEL (FL6) GTM DENSIFICATION

RICE:	2.47781	BSGcomp	2.301
BSG(Agg)	2.644	HTcomp	2.602
BINDER %	4.7	REVcomp	15

SAMPLE SGAR47.7

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.546	9.5	26.9	2.352	146.7	5.1	15.2
5	2.516	16.5	53.0	2.358	147.2	4.6	15.0
10	2.506	19.0	54.7	2.361	147.3	4.7	14.9
15	2.499	19.5	56.3	2.363	147.5	4.6	14.8
25	2.488	19.0	55.1	2.366	147.6	4.5	14.7
35	2.480	19.0	55.3	2.366	147.7	4.4	14.7
50	2.469	19.0	58.5	2.370	147.9	4.3	14.6
75	2.456	19.5	57.3	2.374	148.1	4.2	14.4
100	2.447	19.0	56.0	2.376	148.2	4.1	14.4
125	2.439	19.0	56.2	2.378	148.4	4.0	14.3
150	2.432	19.5	57.9	2.379	148.5	4.0	14.2
175	2.426	19.0	56.5	2.381	148.6	3.9	14.2
200	2.421	19.0	56.6	2.382	148.6	3.9	14.1
225	2.416	19.0	56.7	2.383	148.7	3.8	14.1
250	2.411	18.5	55.4	2.385	148.8	3.8	14.1
300	2.401	19.5	56.6	2.387	148.9	3.7	14.0

SAMPLE SGAR47.8

REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.605	10.0	27.7	2.298	143.4	7.2	17.2
5	2.564	16.0	50.7	2.316	144.5	6.5	16.5
10	2.549	16.5	52.4	2.322	144.9	6.3	16.3
15	2.538	16.5	52.6	2.327	145.2	6.1	16.1
25	2.524	16.5	52.9	2.333	145.6	5.9	15.9
35	2.512	19.0	54.6	2.338	145.9	5.7	15.7
50	2.497	16.5	53.5	2.344	146.3	5.4	15.5
75	2.481	19.0	55.3	2.351	146.7	5.1	15.3
100	2.468	19.0	55.6	2.356	147.0	4.9	15.1
125	2.459	19.0	55.8	2.360	147.3	4.8	14.9
150	2.450	19.0	56.0	2.364	147.5	4.6	14.8
175	2.443	19.0	56.1	2.367	147.7	4.5	14.7
200	2.436	19.0	56.5	2.370	147.9	4.4	14.6
225	2.428	19.0	56.5	2.373	148.1	4.2	14.5
250	2.423	19.0	56.6	2.375	148.2	4.1	14.4
300	2.414	19.5	56.5	2.379	148.4	4.0	14.3

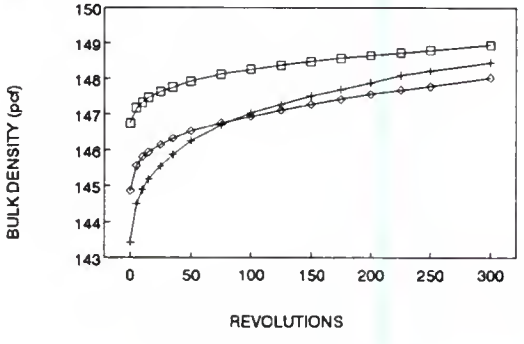
SAMPLE SGAR47.9

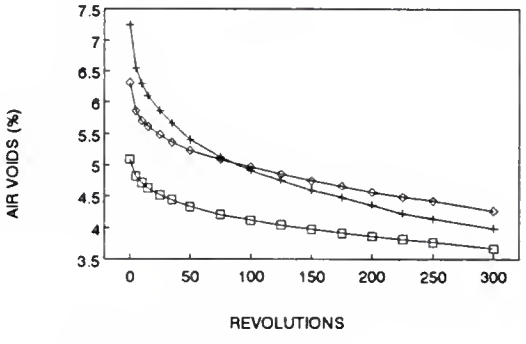
REV	HT.	ARP	Gs	BSG	B DENS	A.V.	VMA
0	2.579	10.0	28.0	2.322	144.9	6.3	16.5
5	2.544	16.0	51.1	2.333	145.6	5.9	15.9
10	2.532	16.5	52.7	2.337	145.8	5.7	15.8
15	2.525	19.0	54.3	2.339	145.9	5.6	15.7
25	2.515	19.0	54.5	2.342	146.1	5.5	15.6
35	2.506	19.5	56.2	2.345	146.3	5.4	15.5
50	2.496	20.0	57.6	2.348	146.5	5.2	15.4
75	2.485	20.0	56.1	2.352	146.7	5.1	15.2
100	2.476	19.0	55.4	2.355	146.9	5.0	15.1
125	2.467	19.0	55.6	2.356	147.1	4.9	15.0
150	2.459	19.0	55.6	2.360	147.3	4.8	14.9
175	2.452	18.5	54.4	2.362	147.4	4.7	14.9
200	2.445	18.5	54.6	2.365	147.6	4.6	14.8
225	2.439	18.0	53.3	2.367	147.7	4.5	14.7
250	2.434	18.0	53.4	2.368	147.8	4.4	14.6
300	2.422	18.0	53.6	2.372	148.0	4.3	14.5

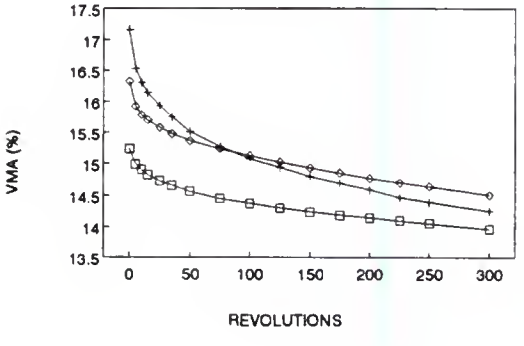
AVERAGE

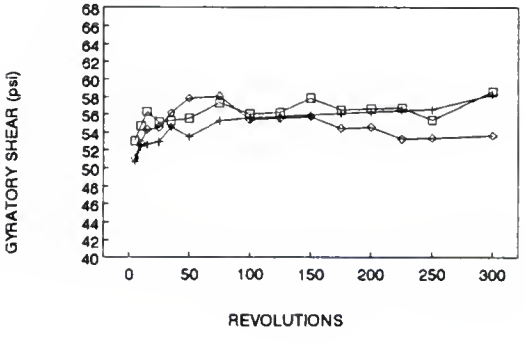
REV	Gs	BSG	B DENS	A.V.	%TMD	VMA
0	27.5	2.324	145.0	6.2	95.6	16.2
5	51.6	2.336	145.7	5.7	94.3	15.6
10	53.5	2.340	146.0	5.6	94.4	15.7
15	54.4	2.343	146.2	5.4	94.6	15.6
25	54.2	2.347	146.4	5.3	94.7	15.4
35	55.3	2.350	146.6	5.2	94.8	15.3
50	55.6	2.354	146.9	5.0	95.0	15.1
75	56.9	2.359	147.2	4.8	95.2	15.0
100	55.7	2.362	147.4	4.7	95.3	14.9
125	55.6	2.365	147.6	4.5	95.5	14.8
150	56.5	2.368	147.7	4.4	95.6	14.7
175	55.7	2.370	147.9	4.4	95.6	14.6
200	55.6	2.372	148.0	4.3	95.7	14.5
225	55.5	2.374	148.2	4.2	95.8	14.4
250	55.1	2.376	148.3	4.1	95.9	14.4
300	56.6	2.379	148.5	4.0	96.0	14.2

MIX ID: SGAR









APPENDIX D
COMPARISON OF STABILIZING ADDITIVES FOR SMA MIXTURES

COMPARISON OF STABILIZING ADDITIVES FOR SMA MIXTURES

Introduction

This appendix is a short report on a laboratory evaluation of some of the common stabilizing additives used in SMA mixtures as well as some additives with some history of use in DGAC mixtures. The purpose of this study was to compare the effects of the different stabilizers on mitigating binder draindown, resistance to compaction, and tensile properties of SMA mixtures. This testing was performed by the Florida Department of Transportation's Bituminous Research Laboratory in conjunction with the research reported in the body of the dissertation.

Materials

Eight stabilizing additives were compared in this study. The following table identifies the stabilizers, their sources, and the suppliers' recommended dosages as used in the SMA mixtures.

Table D1. Stabilizing Additives

Stabilizing Additive	Brand Name	Supplier/Manufacturer	Dosage
cellulose fiber	CF31500	Custom Fibers, Inc.	0.3 % of total mix
ground tire rubber	GF 80	Rouse Rubber, Inc.	12 % of a.c.
low density polyethylene	Novophalt	Novophalt America, Inc.	5 % of a.c.
nylon fibers	N 66 waste carpet fiber	Du Pont, Inc.	0.3 % of total mix
polyester fiber		High Tech Fibers, Inc.	0.3 % of total mix
polypropylene fiber	Fiber Pave 3010	Hercules Fibers, Inc.	0.3 % of total mix
slag wool fiber	Slag Wool AG	Sloss Industries, Inc.	0.4 % of total mix
polyolefin polymer	Vestoplast		7 % of a.c.

The base mixture used in this evaluation was the SMA mixture identified as FL1 in Chapter 5. This mixture is composed of limestone aggregates from Dade County, Florida, and the mineral filler, RO4, from Georgia Marble Co. The blended gradation of the aggregates is shown in Table 7 on page 49. The asphalt was an AC-30, PG 64-22, from Coastal Fuels.

Test Procedures

Mixture samples with each stabilizer were tested in accordance with the NCAT Draindown Test to determine the percent of binder draindown over a range of asphalt contents. Samples were also compacted at two or more asphalt contents in the Gyratory Testing Machine to assess the effect of the stabilizer on compactability of the mixtures. Tensile strengths and failure strains of the compacted samples were also determined as described Chapter 5.

Results and Discussion

The results of the NCAT Draindown Tests are shown in Table D2. These results show that cellulose fiber was the most effective stabilizer in mitigating draindown of the binder, followed closely by Novophalt and polyester fiber. Ground tire rubber was also very effective in preventing the runoff of the binder. These four stabilizers (cellulose fibers, Novophalt, polyester fibers and GTR) each easily passed the TWG criteria of 0.3 percent maximum loss at the highest binder content tested, 6.5 percent. All of the other stabilizers failed to meet this criteria, even at an asphalt content of 5.5 percent. Vestoplast and polypropylene fibers had only minimal improvement over the control samples.

Table D2. Percent Draindown By Weight of Total Mix

Asphalt Content	5.0 %				5.5 %				6.0 %				6.5%			
Time (hrs.)	1	1	1.5	2	0.5	1	1.5	2	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
Control	0.50	0.67	0.80	0.92	0.77	1.31	1.66	1.88	2.76	3.74	4.18	4.44	4.35	5.51	5.96	6.11
Cellulose Fiber	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.04
GTR	0.04	0.05	0.05	0.05	0.02	0.03	0.04	0.04	0.07	0.07	0.11	0.11	0.06	0.06	0.12	0.12
Novophalt	0.01	0.01	0.01	0.01	0.04	0.05	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Nylon Fiber	0.06	0.07	0.07	0.07	0.18	0.23	0.28	0.34	0.23	0.31	0.54	0.78	0.94	1.29	1.57	1.88
Polyester Fiber	0.02	0.02	0.02	0.03	0.02	0.02	0.04	0.06	0.02	0.02	0.02	0.03	0.03	0.04	0.06	0.08
Polypropylene Fiber	0.22	0.22	0.22	0.23	0.30	0.81	1.00	1.18	1.97	3.02	3.31	3.58	3.23	4.40	4.78	5.00
Slag Wool Fiber	0.16	0.17	0.17	0.33	0.26	0.36	0.42	0.49	1.13	1.38	1.55	1.77	1.65	2.31	2.58	2.82
Vestoplast	0.60	0.71	0.84	0.94	0.69	0.97	1.23	1.43	1.04	1.66	2.07	2.42	3.58	4.81	5.44	5.76

Mixture samples with each of the stabilizers were compacted in the GTM to 15 gyrations. Samples of each mixture were first prepared at an asphalt content of 6.0 percent to make comparisons of volumetric and tensile strength properties at an equal asphalt content. Results of these samples are shown in Table D3. From these data, it can be seen that the stabilizers result an higher in air void contents compared to the control mixture. The cellulose, polyester, and polypropylene fibers all bulked the mixtures substantially. Slag wool fiber, Novophalt, and Vestoplast increased the resistance to compaction only slightly. The mixtures containing ground tire rubber and nylon fibers had moderately higher air void contents compared to the control mixture. Comparison of tensile strengths indicates that most of the additives have a negligible effect relative to the control. The three stabilizers which appear to provide a significant improvement in tensile strength are ground tire rubber, Novophalt, and Vestoplast. However, these additives, particularly Novophalt, also appear to reduce the failure strain. Additives which appear to slightly improve strain at failure, in comparison to the control mixture, include cellulose fiber, nylon fiber, polyester fiber and polypropylene fiber.

Mixtures were also prepared at other asphalt contents in order to achieve air void contents within the ranges of 6 to 7 percent and 8 to 9 percent so that a comparisons could be made between tensile properties at nearly equal densities. Results of these tests are shown in Table D5.

Table D3. Results of Compacted Air Void Contents and Tensile Properties at 6.0% Asphalt Content

Stabilizer	Air Void Content (%)	Tensile Strength (psi)	Failure Strain (%)
Control	6.2	75.6	1.21
Cellulose Fiber	8.4	83.7	1.41
GTR	7.0	105.0	1.14
Novophalt	6.5	102.1	0.54
Nylon Fiber	7.4	72.5	1.44
Polyester Fiber	8.5	71.1	1.35
Polypropylene Fiber	8.7	76.0	1.46
Slag Wool Fiber	6.6	82.6	1.22
Vestoplast	6.7	99.6	0.89

At the 6 to 7 percent air void content range, which is the target range for selecting the design asphalt content, the results show that mixtures with GTR and Novophalt have significantly higher tensile strengths, however, the Novophalt mixtures still had low failure strains. Mixtures containing polyester fibers, polypropylene fibers, and nylon fibers, which had high air void contents at 6.0 percent asphalt, had improved tensile strengths with slightly higher asphalt contents. Each of the mixtures containing fibers, except for the slag wool fiber, also had significantly higher failure strains than the control mixture.

The results of the samples with 8 to 9 percent air voids show that the reduction in asphalt content generally caused a decrease in tensile strength for all of the mixtures. At this air void range, all of the mixtures appear to have similar tensile strengths, except for the mixture containing Novophalt, which appears to have significantly higher tensile strength. However, the failure strain for Novophalt mixture is again the lowest among all

of the mixtures. At this density range, the mixtures with cellulose fiber, polyester fiber and polypropylene fiber again have superior failure strains.

Table D5. Results of Tensile Tests at Equal Densities

Target Air Void Range	6 - 7 %				8 - 9 %			
Stabilizer	Asphalt Content (%)	Air Void Content (%)	Tensile Strength (psi)	Failure Strain (%)	Asphalt Content (%)	Air Void Content (%)	Tensile Strength (psi)	Failure Strain (%)
Control	5.9	6.8	88.4	1.10	5.0	8.8	87.8	0.77
Cellulose Fiber	7.0	6.4	88.6	1.63	6.0	8.4	83.7	1.41
GTR	6.2	6.0	120.7	1.07	5.0	9.3	83.7	0.77
Novophalt	6.0	6.5	127.5	0.52	5.0	8.7	107.3	0.54
Nylon Fiber	6.5	6.5	101.0	1.27	5.0	9.1	90.8	0.81
Polyester Fiber	7.0	6.0	91.6	1.47	6.0	8.5	71.1	1.35
Polypropylene Fiber	7.0	7.0	95.4	1.42	6.0	8.7	76.0	1.46
Slag Wool Fiber	6.0	6.2	102.6	1.08	5.0	8.7	89.7	0.81
Vestoplast	6.0	7.0	109.8	0.91	5.0	9.1	86.1	0.73

BIOGRAPHICAL SKETCH

Randy Clark West earned his Bachelor of Civil Engineering degree from Auburn University in 1987. He continued on to receive a MSCE degree with an emphasis in pavement materials from Auburn in 1989. Since August 1988, he has been employed by the Florida Department of Transportation as Bituminous Research Engineer. He has worked on a variety of assignments in the asphalt pavements field including the development of specifications, test procedures and training materials, pavement distress investigations, as well as numerous research projects on topics such as asphalt-rubber, glasphalt, loaded wheel testing, resilient modulus testing, and SMA. He has been a registered Professional Engineer in the State of Florida since August 1990. He began attending classes part-time at the University of Florida in August 1989. In August 1991, he was granted one year of educational leave with pay by the Department of Transportation to complete his coursework toward a PhD.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quantity, as a dissertation for the degree of Doctor of Philosophy.

Byron E. Ruth, Chairman
Professor of Civil Engineering

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quantity, as a dissertation for the degree of Doctor of Philosophy.

Mang Tia
Professor of Civil Engineering

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Guerry McClellan
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quantity, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Engineering and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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